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TASK 4 FINAL REPORT

# ELEVATED TEMPERATURE MAGNETIC TAPE PERFORMANCE

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## FOREWORD

This program was directed at the evaluation of two high temperature tapes which indicate initial compatibility with existing low temperature tapes presently used in the majority of commerical aircraft today. Two tapes, Graham Magnetics 465D and IITRI High Temperature Tape, were compared for basic compatibility in use as well as additional environmental benefits available.

The testing in general showed an increase in thermal operating characteristics from the present 200°F to over 800°F with minimal reproduce signal degradation of the IITRI High Temperature and a slightly higher degradation in performance of the Graham 465D.

Several compatibility problems were discovered, principally the lack of a thermally stable, low friction backcoating on either high temperature tape.

Recommednations are made regarding the development of a low friction backcoating for those applications which require endless loop tape operation. This backcoating could be easily applied to the tested high temperature tapes to provide tapes totally compatible with existing tapes, which provide thermal resiliancy to over 800°F.

IITRI has been pleased to perform the required testing under this NASA Task Order contract to the Department of Transportation, National ~~Experimental Facilities~~ Center, and would welcome the opportunity to discuss the program results and recommendations to cognizant DOT personnel.

Respectfully submitted,

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## 1. INTRODUCTION

### 1.1 Objectives

The project objectives were:

(a) To determine whether or not a plastic-based magnetic tape exists which could provide increased survivability in the event of airplane crash recorder thermal exposure.

(b) To determine whether those tapes which provide increased thermal protection are compatible with existing plastic based tapes to the extent that such tapes could directly replace present tapes without flight recorder modification.

The objectives were addressed by the work statement and test procedures which are included in this report as Appendix A.

### 1.2 Background

Various flight recorders are used in American commercial aviation today for the collection of limited amounts of data. These data are considered of utmost importance in the reconstruction of events leading up to an airplane crash. On several occasions in the past years, all data was lost from the airplane recorder because of inability of the recorder to operate correctly or because the recorder and/or the magnetic media was not capable of surviving the crash.

The principal cause for both the recorder not operating correctly and/or not surviving the crash has been found to be the inability of magnetic recording media to survive exposure to the environment.

As a result of these survivability problems, the Department of Transporation, FAA, Systems Research and Development Service directed the National Aviation Facilities Experimental Center (NAFEC) to conduct a program designed to develop a magnetic tape which could provide survivability in the event of a crash.

The requirement for a thermally improved tape remained, however. IITRI notified NAFEC of two existing candidate tapes which possibly could provide for improved thermal properties in flight recorder crashes. These two candidate tapes would provide for better thermal properties because of their base film characteristics.

The comparison of these two thermally stable tapes with a conventional tape was the subject of this program.

### 1.3 Magnetic Tape Characteristics

Magnetic tape has traditionally been an environmentally sensitive information storage media. This is inherent to the configuration chosen, that of a coiled ribbon, which allows for long recording times and relatively rapid access to the stored information. A coiled ribbon must, of necessity, be thin, flexible and physically strong. Manufacturers through the years have utilized various bases for magnetic tape which afford the above mentioned characteristics. Some basefilms utilized include paper, cellulose acetate, acetate, polyvinyl chloride, cellophane, polyethylene terepthylate (Mylar$^R$), polyimide (Kapton$^R$), and steel. Each of the above have found some acceptance and the limitations of each are well documented.

If a basefilm were selected for tape usage principally for thermal properties, one would pick steel (or some other metallic film). Problems with metallic bases for magnetic tape include poor flexibility, shape retention, poor surface finish, and poor oxide adhesion properties. A problem caused by the poor flexibility, that of increased tension necessary to maintain adequate head to tape contact, is perhaps the greatest problem in application. The necessity for increased tension at the record/reproduce heads causes excessive head wear as well as a high degree of oxide shed from the metallic surface. These conditions are not conductive to highly reliable long life recording system.

Metallic based tapes are presently in limited usage for cockpit voice recorders on widebodied aircraft in commercial aviation. Numerous reliability and maintainability problems are reported.

Kapton based tapes are also in limited usage on instrumentation recorders on the newer wide bodied aircraft. The remaining aircraft,(i.e., Boeing 707, 720, 727, 737, Douglas DC8, DC9, and Lockheed Electra), comprising the vast majority of aircraft in use today, are using conventional Mylar$^R$ based tape. The purpose of this study was thus to determine whether existing Kapton$^R$ based tapes could be substituted for Mylar$^R$ based tapes for flight recorder use, without extensive flight recorder modification.

Other considerations in the development of a high temperature tape are the ingredients used in manufacture. It is not only important that the basefilm survive the thermal exposure but the coated oxide formulation must also survive in order for the tape to be reproducible.

A conventional tape oxide formulation consists of combinations of the following ingredients:

1. Active (Oxide) Side:

    a. Magnetic Oxide

        1. Gamma Ferric Oxide ($Fe_2O_3$)
        2. Magnatite ($Fe_3O_4$)
        3. Nickle Doped $Fe_2O_3$
        4. Cobalt Doped $Fe_2O_3$
        5. Combination Ni Co doped $Fe_2O_3$
        6. Chromium Dioxide ($CrO_2$)

b. Binder

1. Saran (vinyl chlorides)
2. Vinyl
3. Urethane
4. Estane
5. Epoxide
6. Polyamide
7. Polyimide

c. Dispersion Promotion Agent

d. Carbon

e. Plasticizers and Softener

f. Fungicide

g. Lubricant

2. <u>Back (Friction) Side</u>

a. Carbon (high friction)

b. Graphite (low friction)

c. Binder (same as above)

d. Dispersion Promotion Agents

e. Plasticizers and Softeners

It is obvious that for a tape to survive temperatures in the vicinity of $800^{\circ}F$, as the work statement for this testing specifies, not only the base film, but all ingredients utilized in the tape's construction must be capable of surviving exposure to the temperature.

Of the aforementioned ingredients, only the following have been identified as being capable of survival at elevated temperatures:

1. Active (Oxide) Side:

   a. Magnetic Oxide -- Gamma Ferric Oxide ($Fe_2O_3$)

   b. Binder -- Polyimide

   c. Dispersion Promotion Agent -- Triton X-100

   d. Carbon -- any type suitable

   e. Plasticizers and Softeners -- not yet found

   f. Fungicides -- none

   g. Lubricants -- none in formulation, surface-Krytox$^R$

Thus it can be seen that to ensure tape survivability at elevated temperature the ingredients must be carefully selected. Not only must every ingredient be tested to determine thermal stability, but the total formulation must be tested to ensure chemical formulation thermal compatibility.

## 1.4 Selected Candidates

The selected candidates for testing under this program included the following:

1. Graham Thermo 465D

2. IITRI High Temperature Polyimide 5 Year Tape

These tapes were evaluated against the prevalent backside lubricated tape presented used in the older jet aircraft, 3M 156, manufactured by Minnesota Mining and Manufacturing Company.

The Graham Thermo 465D incorporates Gamma Ferric Oxide together with an unknown binder coated on Kapton. Graham Graham Thermo 465D has previously been tested and been found acceptable by IITRI to temperatures to $500^{\circ}F$.

The IITRI High Temperature Polyimide 5 Year Tape (IITRI) has been formulated to provide operational capability to temperatures in excess of $800^{\circ}F$ with the following ingredients:

1. Gamma Ferric Oxide, Pfeizer MO-2228

2. Binder, Amoco Polyimide DE-923

3. Carbon, Vulcan XF-243

4. Dispersion Promotion Agent, Rohm-Haas Triton X-100

5. Surface Lubrication, Krytox$^R$

6. No Backcoating

7. Coated on Kapton$^R$ Base Film

The presently utilized tape, 3M 156, against which the above high temperature candidates were evaluated consists of the following known ingredients:

1. Gamma Ferric Oxide

2. Binder, Polyurethane Vinyl Urethane

3. Carbon

4. Dispersion Promotion Agent

5. Internal Lubricant, Silicone, etc.

6. Fungicide

7. Plasticizers, Vinyl Chloride

8. Base Film - Mylar®

These candidates were selected as being the only known tapes which could survive the anticipated thermal testing, while providing some compatibility with the existing 3M 156, It should, however, be pointed out that neither of the selected candidates provide for a lubricating backcoating. 3M 156 provides a graphite lubricated backcoating which is necessary to provide for endless loop cartridge operation. Neither the Graham or IITRI tapes as tested have the required lubricated backside. Discussion with Graham indicate that no capability or desire exists to provide this high temperature tape with backside lubricant. IITRI could, under a developmental program, provide its high temperature tape with a graphite lubricated backcoating.

## 1.5 Testing Procedures

All tests were performed in accordance with the work statement and test procedure/specifications issued by NAFEC. A copy of these specifications is included as Appendix A of this report.

## 2. TECHNICAL DISCUSSION

In accordance with the statement of work, IITRI performed selected tests on two lots of high temperature tape and one lot of conventional tape. A copy of this specification is included in Appendix A of this report. The selected testing consisted of the following 22 tests.

1. Sensitivity
2. Distortion at Standard Record Level
3. Distortion at Maximum Record Level
4. Uniformity
5. Bias Variation
6. Layer to Layer Signal Transfer
7. Frequency Response
8. Signal to DC Noise Ratio
9. Ease of Erasure
10. Low Temperature Environment Test
11. Elevated Temperature Environment Test
12. Severe Temperature Environment Test
13. Humidity Environment Test
14. Water Immersion
15. Hydraulic Fluid Immersion Environment Test
16. Jet Fuel Immersion Environment Test
17. Severe Temperature Layer to Layer Adhesion
18. Yield Strength
19. Shock Tensile Strength
20. Elongation Under Stress
21. Humidity Stability (Cupping)
22. Tape Life Test

## 2.1 Severe Temperature Test

Environmental tests performed under this project were designed with primary objective being to obtain information regarding the behavior of three types of recording tapes when exposed to various severe thermal environments. These consisted of various temperature and relative humidity-testing of prerecorded tapes constructed of Mylar and Kapton base. A complete 1000 foot reel of these tapes, were prerecorded with a 4000 Hz signal at standard record levels, served as a yardstick in post-test signal loss analysis. The standard record levels are shown on Figures 1 through 6. Tape specimens approximately 100 feet long were cut from these master tapes and prepared for testing. The effect of the tests was measured in terms of the signal change which is shown in environmental test Matrix I and II.

The post-test signal change results given in environmental test Matrix I and II, indicate varying effects of temperature, relative humidity, water immersion, hydraulic fluid and jet fuel. All results, except that of severe temperature test, for tapes under performance are within the limitation of a maximum loss of 2 dB. The results of severe temperature test indicate an acceptable heat resistance up to the 800°F test level in IITRI High Temperature 5 Year tape without backcoating. The Graham Thermo 465D tape with backcoating is also playable but the signal is degraded by 9 dB. The 3M 156 Mylar base tape is completely destroyed and shown in Figure 9. Both the Graham Thermo 465D tape and IITRI High Temperature 5 Year tape remained flexible without sticking together of adjacent layers for the 45 minute exposure. However, it was observed that the edges of the tape were extremely curled as shown on Figures 7 and 8. The Graham Thermo 465D has a friction promoting carbon black coating on the backside. This backcoating made the edge of tape severely curled because of the large differential coefficient of expansion among the oxide side, substrate and backcoating under 800°F temperature exposure.

2.2 Water Immersion Test

One hundred foot specimens of tape were immersed in sea water for 30 days. The sea water used is available commercially under designation Marineland sea mix from the Marineland Aquarium Products Inc., California. After 30 days immersion, these samples were removed and washed with distilled water and air dried overnight. The test results are shown in Environmental Test Matrix II. The reproduce signal indicated no change.

2.3 Hydraulic Fluid Exposure

One hundred foot specimens were immersed in Skydrol 500 type hydraulic fluid for a period of 120 hours, removed and then placed in a Gravity Convection Oven at 72°C (161.6°F) for 120 hours. The specimens then cooled under normal atmospheric conditions overnight and were washed in a bath of benzene solvent to remove the skydrol hydraulic fluid. The post test signal results are shown in Environmental Test Matrix II and indicate no signal loss. However, it was observed that the edges of the oxide side of the Graham Thermo 465D tape were stripped out slightly. This is mainly because of the chemical reaction of hydraulic fluid with oxide and the friction carbon black coating.

2.4 Humidity Environment

The 100 foot specimens were placed in an environmental chamber manufactured by Tenney Engineering Inc. at temperature 70° ± 2°C (158 ± 5°F) and a relative humidity of 95 ± 5% for six hours. The temperature was then changed to 38°C (100°F) and then remained for 18 hours. This complete cycle was repeated three times. The post signal test results are shown in Environmental Test Matrix I and indicate no reproduce signal change.

2.5 Low Temperature Environment

The specimens were placed in a precision series temperature chamber, manufactured by Delta Design, California, at a temperature of -25°C for five hours. The specimens were then returned to room temperature for a period of five hours. The post-signal test results are shown in Environmental Test Matrix I and indicates no reproduce signal change.

2.6 Elevated Temperature Environment

The specimens were exposed to an ambient temperature of 70°C (158°F) in a Gravity Convection Oven for 24 hours, followed by exposure to -25°C (-13°F) in a precision series temperature test chamber for another 24 hours, followed immediately by exposure to room temperature for 3 hours. There is no evidence of damage as a result of exposure to these conditions. The post test reproduce signal test results are shown in Environmental Test Matrix I and indicate no reproduce signal change.

2.7 Tape Life Test

The loop transport head is lapped to high polish (resolution: 5.0 microinches). A 54 inch loop of the tape specimen is mounted on the transport and driven for 518,000 passes under the following conditions:

Tape speed = 30 ips

Tape tension = 4 oz.

Head wrap angle = 15° work statement proposed specs call for 30°

Head type = chrome type head work statement proposed specs calls for aluminum

Upon completion of test a sample of tape is mounted for visual comparison to other specimens that have undergone the same test. Finally the head is again profiled and head-wear determined. The test results are shown in the Physical Characteristics Test Matrix. The Graham Thermo 465D had the least head wear and IITRI Kapton tape had a head wear of 65 micro- ? inches which also meets the requirements. ? How can this be 'work statement calls for head wear of less than 70 u in after 1,000,000 passes

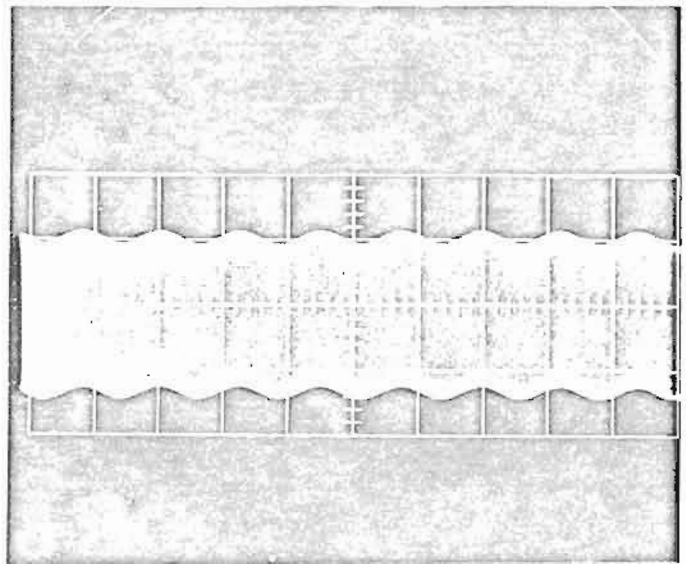

Fig. 1 3M 156 STANDARD RECORD LEVEL

10 MA/cm

Frequency = 4000 cps
Input Current = 2.4 MA
Bias Current = 23 MA
Third Harmonics = 0.5 MV

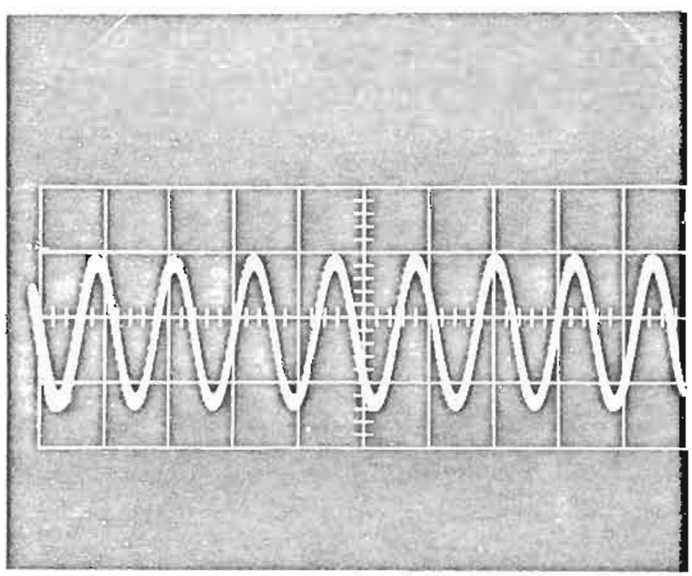

Fig. 2 3M 156 STANDARD RECORD LEVEL REPRODUCE OUTPUT

0.2 V/cm

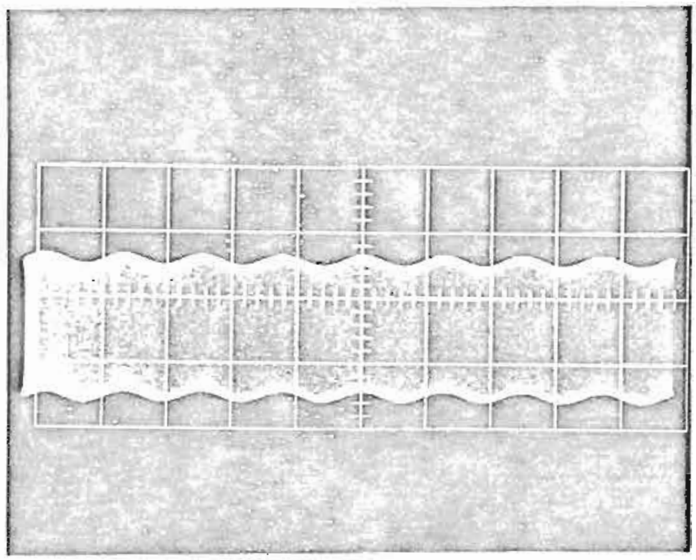

Fig. 3 Graham 465D STANDARD RECORD LEVEL

Frequency = 4000 cps
Input Current = 3.5 MA
Bias Current = 20 MA
Third Harmonics = 0.05 MV

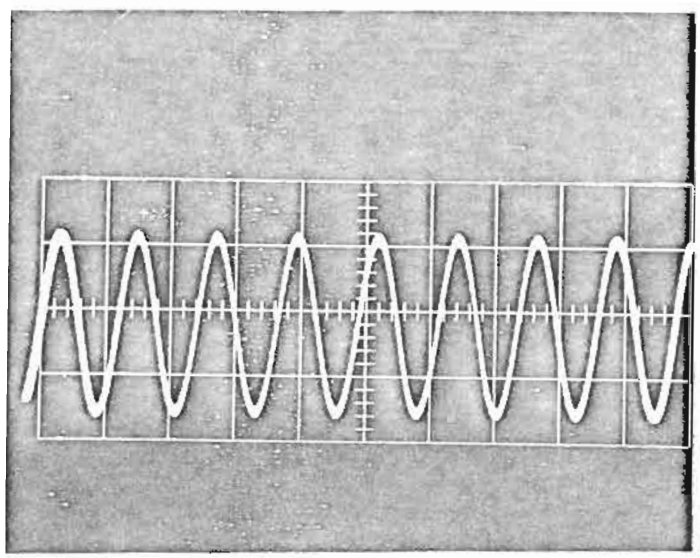

Fig. 4 GRAHAM 465D STANDARD RECORD LEVEL REPRODUCE OUTPUT

0.2 V/cm

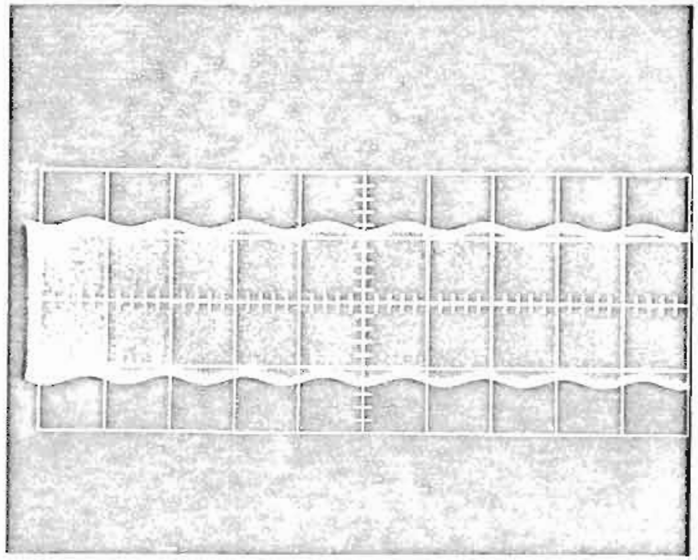

Fig. 5 IITRI KAPTON TAPE STANDARD RECORD LEVEL

Frequency = 4000 cps
Input Current = 1.6 MA
Bias Current = 24 MA
Third Harmonics = 0.2 MV

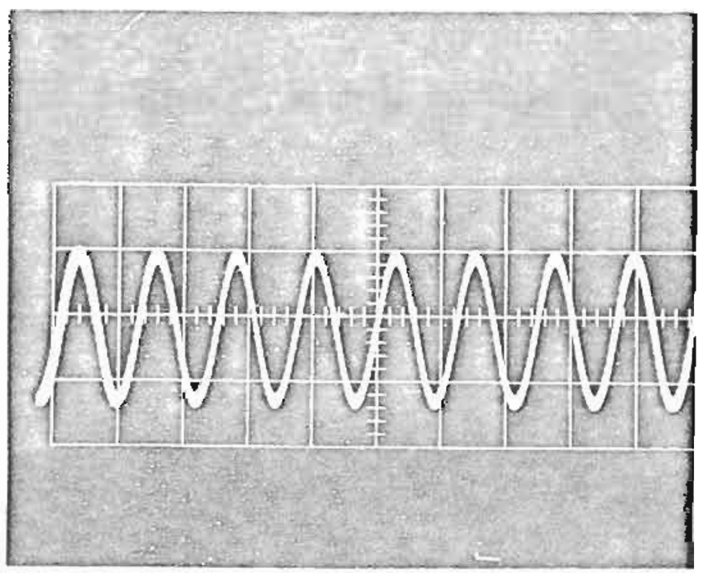

Fig. 6 IITRI KAPTON TAPE STANDARD RECORD LEVEL REPRODUCE OUTPUT
100 MV/cm

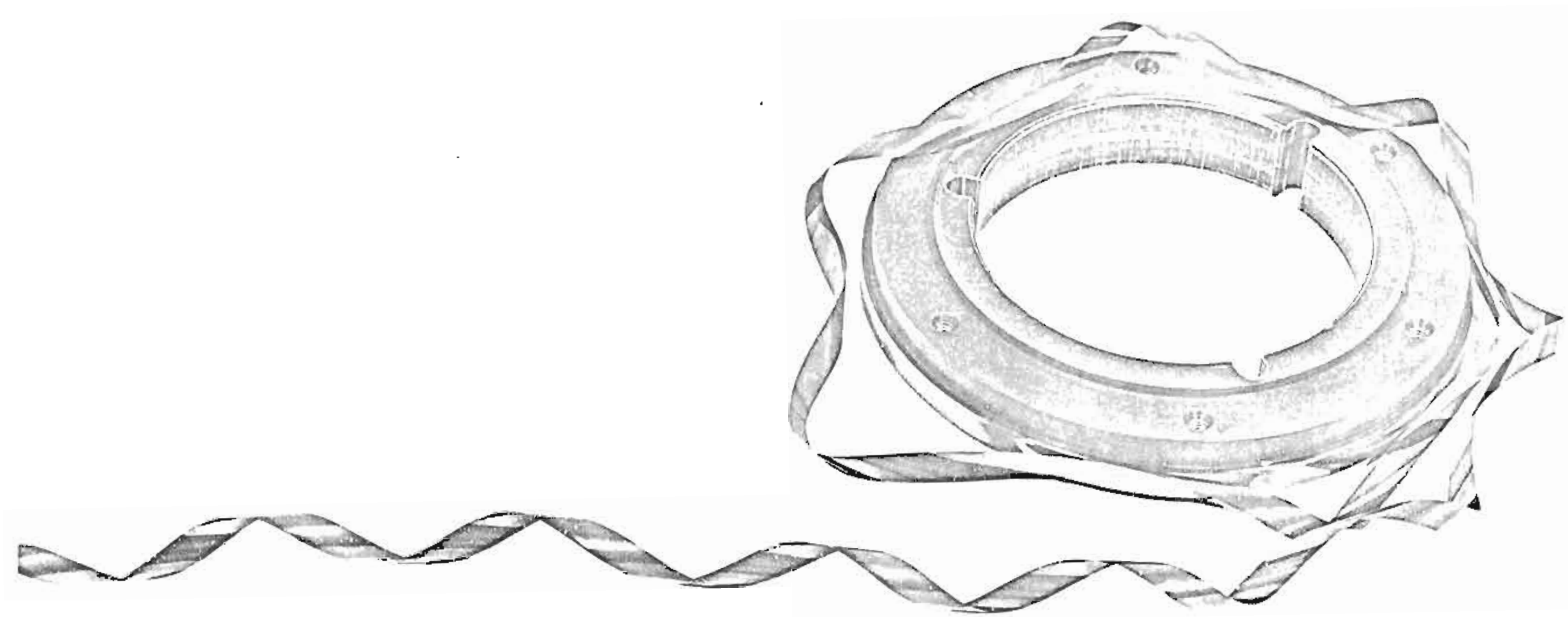

Fig. 7 IITRI KAPTON TAPE, 800$^{\circ}$F, EXPOSURE TIME 45 MINUTES

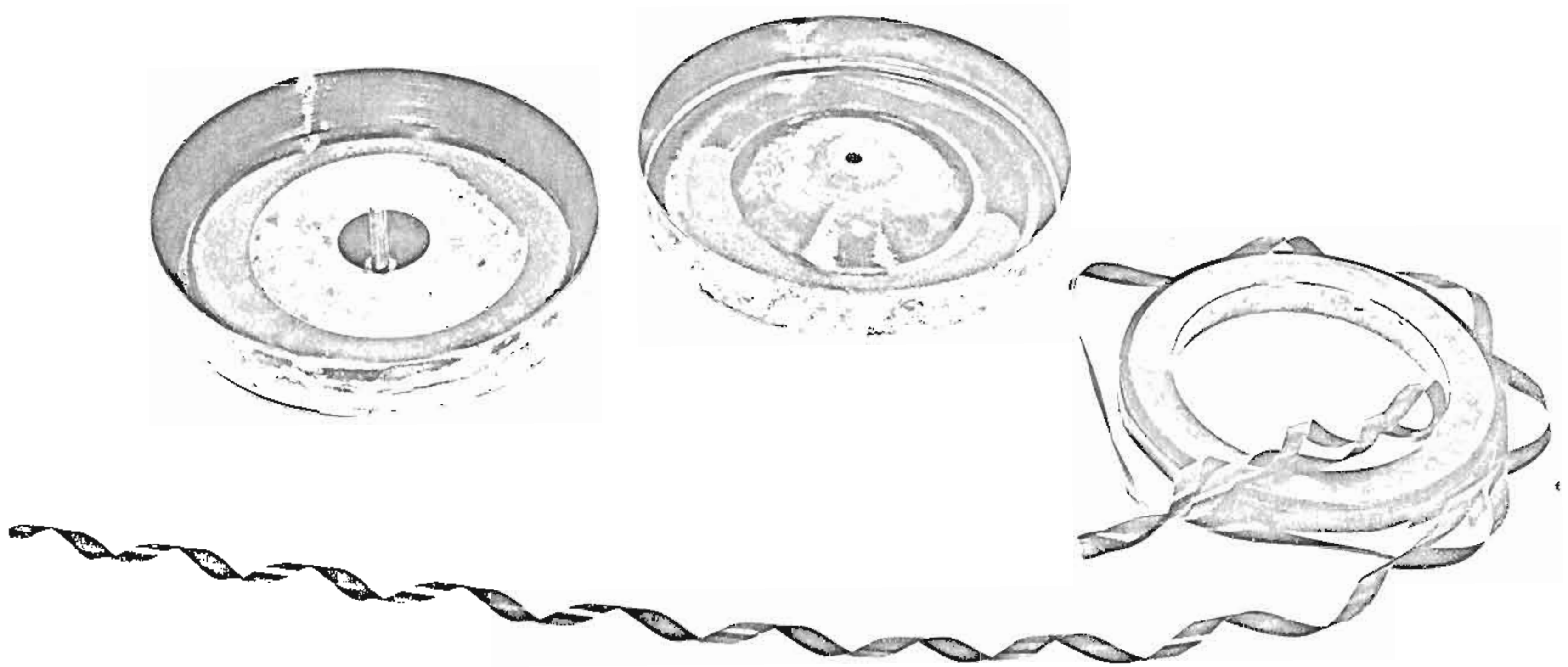

Fig. 8 GRAHAM THERMO 465D, 800$^{\circ}$F, EXPSOURE TIME 45 MINUTES

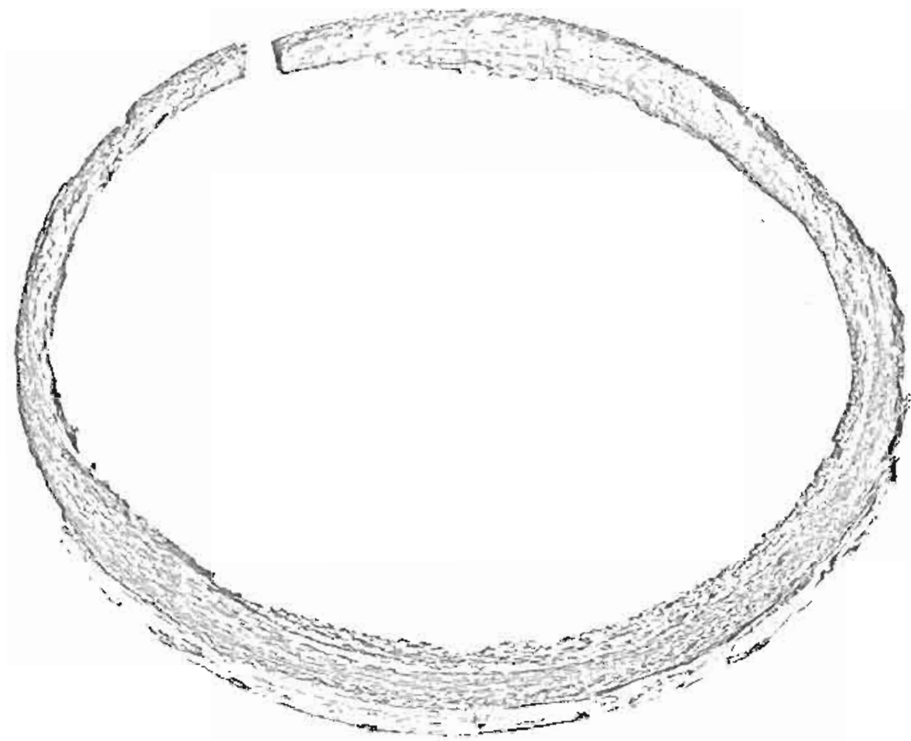

Fig. 9 3M 156, $800^{\circ}F$, EXPOSURE TIME 45 MINUTES

ENVIRONMENTAL TEST MATRIX FOR NAFEC TAPE EVALUATION (I)

| TEST \ TAPE TYPE | REFERENCE TAPE 3M 156 | GRAHAM TAPE THERMO 465D | IITRI KAPTON TAPE (UNORIENTED) |
|---|---|---|---|
| Standard * Recording Level | Frequency = 4000 Hz<br>Input Current = 2.4 ma<br>Bias Current = 23 ma<br>Third Harmonic = 0.5 mvrms<br>Reproduce Output = 0.16 ~~m~~vrms | Frequency = 4000 Hz<br>Input Current = 3.5 ma<br>Bias Current = 20 ma<br>Third Harmonic = 0.05 mvrms<br>Reproduce Output = 0.2 vrms | Frequency = 4000 Hz<br>Input Current = 1.6 ma<br>Bias Current = 24 ma<br>Third Harmonic = 0.2 mvrms<br>Reproduce Output = 0.08 ~~μ~~vrms |
| Low Temperature Test | Reproduce Output = 0.16 vrms<br>No Change | Reproduce Output = 0.2 vrms<br>No Change | Reproduce Output = 0.08 vrms<br>No Change |
| Elevated Temperature | Reproduce Output = 0.16 vrms<br>No Change | Reproduce Output = 0.2 vrms<br>No Change | Reproduce Output = 0.08 vrms<br>No Change |
| Severe Temperature | Tape Destroyed at 800°F ** | Reproduce Output = 0.07 vrms<br>9 dB Down *** | Reproduce Output = 0.06 vrms<br>2 dB Down**** |
| Humidity Test | Reproduce Output = 0.16 vrms<br>No Change | Reproduce Output = 0.19 vrms<br>0.45 dB Down | Reproduce Output = 0.08 vrms<br>No Change |
| Remarks<br>*Standard record level shown in Figs. 1-6. | ** Tape is destroyed as shown in Figure 9.<br>Upper limit of the mylar base tape is determined to be 350°F to 400°F. | ***The edge of tape is severely curled but tape still playable. | ****The edge of tape is slightly curled. |

ENVIRONMENTAL TEST MATRIX FOR NAFEC TAPE EVALUATION (II)

| TAPE TYPE / TEST | REFERENCE TAPE 3M 156 | GRAHAM TAPE THERMO 465D | IITRI KAPTON TAPE (UNORIENTED) |
|---|---|---|---|
| Standard Recording Level | Frequency = 4000 Hz<br>Input Current = 2.4 ma<br>Bias Current = 23 ma<br>Third Harmonic = 0.5 mvrms<br>Reproduce Output = 0.16 vrms | Frequency = 4000 Hz<br>Input Current = 3.5 ma<br>Bias Current = 20 ma<br>Third Harmonic = 0.05 mvrms<br>Reproduce Output = 0.2 vrms | Frequency = 4000 Hz<br>Input Current = 1.6 ma<br>Bias Current = 24 ma<br>Third Harmonic = 0.2 mvrms<br>Reproduce Output = 0.08 vrms |
| Water Immersion Test | Reproduce Output = 0.16 vrms*<br>No Change | Reproduce Output = 0.2 vrms<br>No Change | Reproduce Output = 0.08 vrms<br>No Change |
| Hydraulic Fluid Test | Reproduce Output = 0.16 vrms **<br>No Change | Reproduce Output = 0.2 vrms ****<br>No Change | Reproduce Output = 0.08 vrms<br>No Change |
| Jet Fuel Test | Reproduce Output = 0.16 vrms ***<br>No Change | Reproduce Output = 0.2 vrms<br>No Change | Reproduce Output = 0.08 vrms<br>No Change |
| Severe Temp. Layer to Layer Adhesion Test | Tape destroyed at 800°F | No layer to layer adhesion | No layer to layer adhesion |
| Remarks | *Using distilled water to clean up tape.<br>**Using benzene to clean up hydraulic fluid.<br>***Jet fuel is evaporated at 72°C. | ****The edge of oxide side is peeled off slightly due to the chemical reaction of hydraulic fluid with oxide and backcoating. | |

OXIDE CHARACTERISTIC TEST MATRIX FOR NAFEC TAPE EVALUATION (I)

| TEST \ TAPE TYPE | REFERENCE TAPE 3M 156 | GRAHAM TAPE THERMO 465D | IITRI KAPTON TAPE (UNORIENTED) |
|---|---|---|---|
| Sensitivity | Reproduce Output = 0.165 vrms = 0 dB<br>Input Current = 1.9 ma<br>Bias Current = 22 ma<br>Third Harmonic Distortion = 1.3 mvrms = 0.79% | Reproduce Output = 0.13 vrms = -2 dB<br>Input Current = 1.25 ma<br>Bias Current = 19 ma<br>Third Harmonic Distortion = 0.5 mv = 0.38% | Reproduce Output = 0.035 vrms = -13 dB<br>Input Current = 0.8 ma<br>Bias Current = 22 ma<br>Third Harmonic Distortion = 0.05 mv = 0.14% |
| Distortion at Standard Record Level | Third Harmonic = 1.3 mvrms = 0.79%<br>Reproduce Output = 0.165 vrms<br>Input Current = 1.9 ma<br>Bias Current = 22 ma | Third Harmonic = 0.5 mv = 0.38%<br>Reproduce Output = 0.13 vrms<br>Input Current = 1.25 ma<br>Bias Current = 19 ma | Third Harmonic = 0.05 mv = 0.14%<br>Reproduce Output = 0.035 vrms<br>Input Current = 0.8 ma<br>Bias Current = 22 ma |
| Distortion at Maximum Record Level | Third Harmonic = 27 mv = 3%<br>Reproduce Output = 0.9 vrms<br>Input Current = 11 ma<br>Bias Current = 22 ma | Third Harmonic = 21 mv = 3%<br>Reproduce Output = 0.7 vrms<br>Input Current = 7 ma<br>Bias Current = 19 ma | Third Harmonic = 6 mv = 3%<br>Reproduce Output = 0.2 vrms<br>Input Current = 4 ma<br>Bias Current = 22 ma |
| Uniformity at 1000 Hz | 9.5% | 18.5% | 16.4% |
| Uniformity at 5000 Hz | 26% | 31.6% | 38% |
| Bias Variation | 22 ma (+0) | 19 ma (-3) | 22 ma (+0) |
| Layer to Layer Signal Transfer | Layer to Layer Signal Transfer = -47 dB<br>Reproduce Output = +2 dB<br>Transferred Signal = -45 dB<br>Record Input Current = 11 ma<br>Bias Current = 22 ma | Layer to Layer Signal Transfer = -38 dB<br>Reproduce Output = +1 dB<br>Transferred Signal = -45 dB<br>Record Input Current = 7 ma<br>Bias Current = 19 ma | Layer to Layer Signal Transfer = -37 dB<br>Reproduce Output = -10 dB<br>Transferred Signal = -45 dB<br>Record Input Current = 4 ma<br>Bias Current = 22 ma |

OXIDE CHARACTERISTIC TEST MATRIX FOR NAFEC TAPE EVALUATION (II)

| TAPE TYPE / TEST | REFERENCE TAPE 3M 156 | GRAHAM TAPE THERMO 465D | IITRI KAPTON TAPE (UNORIENTED) |
|---|---|---|---|
| Frequency Response Test<br>200 Hz | Reproduce Output = 0.175 vrms<br>Input Current = 1.4 ma<br>Bias Current = 22 ma<br>Third Harmonic = 1 mv = 0.57%<br>Normalized at 1000 Hz Output = +0.5 dB | Reproduce Output = 0.12 vrms<br>Input Current = 1.0 ma<br>Bias Current = 21 ma<br>Third Harmonic = 0.36 mv = 0.39<br>Normalized at 1000 Hz Output = -0.69 dB | Reproduce Output = 0.035 vrms<br>Input Current = 0.8 ma<br>Bias Current = 22 ma<br>Third Harmonic = 0.1 mv = 0.28%<br>Normalized at 1000 Hz Output = 0 dB |
| 5000 Hz | Reproduce Output = 0.155 vrms<br>Input Current = 2.4 ma<br>Bias Current = 24 ma<br>Third Harmonic = 0.85 mv = 0.55%<br>Normalized at 1000 Hz Output = -0.54 dB | Reproduce Output = 0.15 vrms<br>Input Current = 2.5 ma<br>Bias Current = 26 ma<br>Third Harmonic = 0.4 mv = 0.27%<br>Normalized at 1000 Hz Output = +1.24 dB | Reproduce Output = 0.09 vrms<br>Input Current = 1.2 ma<br>Bias Current = 22 ma<br>Third Harmonic = 0.03 mv = 0.33%<br>Normalized at 1000 Hz Output = +8 dB |
| 8000 Hz | Reproduce Output = 0.14 vrms<br>Input Current = 0.8 ma<br>Bias Current = 10 ma<br>Third Harmonic = 0.5 mv = 0.36%<br>Normalized at 1000 Hz Output = -1.4 dB | Reproduce Output = 0.155 vrms<br>Input Current = 1.0 ma<br>Bias Current = 16 ma<br>Third Harmonic = 0.5 mv = 0.32%<br>Normalized at 1000 Hz Output = +1.5 dB | Reproduce Output = 0.09 vrms<br>Input Current = 1.4 ma<br>Bias Current = 22 ma<br>Third Harmonic = 0.05 mv = 0.05%<br>Normalized at 1000 Hz Output = +8 dB |
| Signal to DC Noise Ratio | Signal to DC Noise Ratio = -41.5 dB<br>Reproduce Signal Level = +1.5 dB<br>DC Erase Current = 30 ma<br>Erased Output = -40 dB | Signal to DC Noise Ratio = -43 dB<br>Reproduce Signal Level = 0 dB<br>DC Erase Current = 21 ma<br>Erased Output = -43 dB | Signal to DC Noise Ratio = -35 dB<br>Reproduce Signal Level = -10 dB<br>DC Erase Current = 12 ma<br>Erased Output = -45 dB |
| Ease of Erasure | Ease of Erasure = -52 dB<br>Record Current Level = 11 ma<br>Bias Current = 22 ma<br>Reproduce Level = +2 dB<br>Erase Output Level = -50 dB | Ease of Erasure = -51 dB<br>Record Current Level = 7 ma<br>Bias Current = 19 ma<br>Reproduce Level = +1.0 dB<br>Erase Output Level = -50 dB | Ease of Erasure = -40 dB<br>Record Current Level = 4 ma<br>Bias Current = 22 ma<br>Reproduce Level = -10 dB<br>Erase Output Level = -50 dB |

PHYSICAL CHARACTERISTIC TEST MATRIX FOR NAFEC TAPE EVALUATION

| TEST \ TAPE TYPE | REFERENCE TAPE 3M 156 | GRAHAM TAPE THERMO 465D | IITRI KAPTON TAPE (UNORIENTED) |
|---|---|---|---|
| Yield Strength | 6.79 lbs | 9.9 lbs. | 9.9 lbs. |
| | | 8.4 lbs. After severe temperature test. | 7.7 lbs. after severe temperature test. |
| Shock Tensile Strength | 1.0 ft-lbs | 0.99 ft-lbs | 0.46 ft-lbs |
| | | 0.41 ft-lbs after severe temperature test. | 0.45 ft-lbs after severe temperature test. |
| Elongation Under Stress | 7.44% | 5.0% | 3.04% |
| | | 2.44% after severe temperature test. | 2.925% after severe temperature test. |
| Humidity Stability | 0.4° | 0.5° | 3° |
| Tape Life | 518K passes. 20% of oxide removed.<br>Headwear: chrome 57. 30 μin | 518K passes. No visible wear. No measurable headwear.<br>Headwear: chrome 63. μin | 518K passes. 25% of oxide removed.<br>Headwear: chrome 58. 65 μin |
| Layer to Layer Signal Transfer | Layer to Layer Signal Transfer = -47 dB<br>Reproduce Output = +2 dB<br>Transfer Signal = -45 dB<br>Record Input Current = 11 ma<br>Bias Current = 22 ma | Layer to Layer Signal Transfer = -38 dB<br>Reproduce Output = +1 dB<br>Transfer Signal = =37 dB<br>Record Input Current = 7 ma<br>Bias Current = 19 ma | Layer to Layer Signal Transfer = -37 dB<br>Reproduce Output = -10 dB<br>Transfer Signal = -47 dB<br>Record Input Current = 4 ma<br>Bias Current = 22 ma |

## 3. SUMMARY OF RESULTS AND CONCLUSION.

The objective of this program, to determine whether or not magnetic tapes exist which would provide increased survivability in a crash while insuring compatibility with existing flight recorders are discussed in this section.

### 3.1 Environmental Testing

The following environmental tests had no significant effects on either the existing 3M 156 or the proposed Graham 465D or IITRI High Temperature tapes:

1. Low Temperature Test
2. Elevated Temperature Test
3. Humidity Test
4. Water Immersion Test
5. Hydraulic Fluid Test
6. Jet Fuel Test

The severe temperature environment test affected the performance of all tapes in the remainder of the performance tests. In particular, the results of the Reproduce Output, Layer to Layer Adhesion, Yield Strength, Shock Tensile Strength, Elongation under Stress, and Layer to Layer Signal Transfer tests were affected.

The 3M 156 tape was rendered completely useless by exposure to the 800°F and hence none of the above data was obtainable.

The reproduce output of the Graham tape was reduced 9 dB and the IITRI tape by 2 dB which indicated the IITRI tape to be within the specification.

Both the Graham and IITRI tapes passed the Layer to Layer Adhesion test, with the 3M 156 rendered useless.

The yield strength of both Graham and IITRI tapes were reduced in the severe temperature test, however, even after the exposure, both tapes were stronger than 3M 156 before exposure.

The shock tensile strength of both Graham and IITRI tapes were reduced during the Severe Temperature Test to a figure below 3M 156 before exposure. This would indicate the need for delicate special handling of tapes subjected to this temperature to protect against breakage.

The elongation under stress of both Graham and IITRI tapes were reduced during severe temperature test to a level below 3M 156 before exposure. This reduction in elongation again would indicate the need for gentle handling of tapes exposed to this temperature.

The layer to layer transfer signal was increased following the severe temperature exposure of the Graham and IITRI tapes. This figure which relates to the transfer of recorded data from one layer to either adjoining layer under elevated temperature should not be of concern considering today's advanced analog to digital conversion techniques, coupled with subsequent computer signal processing. Signals of less than 10 dB signal to background recorded noise (i.e., layer to layer transfer) are typically reproducible.

The results of the environmental testing indicate that significant thermal survivability improvement could be expected if either the Graham or IITRI tapes were utilized in flight recorders.

### 3.2 Compatibility Testing

The following tests, designed to determine compatibility of the two high temperature tapes with the presently utilized indicated no significant difference.

1. Distortion at Standard Record Level
2. Distortion at Maximum Record Level
3. Uniformity at 1000 Hz
4. Uniformity at 5000 Hz
5. Bias Variation

6. Frequency Response at 200 Hz

7. Frequency Response at 5000 Hz

8. Frequency Response at 8000 Hz

9. Signal to DC Noise Ratio

10. Ease of Erasure

The reproduce output of the two elevated temperature tapes was not compatible with that of the 3M 156. The Graham 465D tape had too much reproduce output while the IITRI tape had too little output at the standard record level. The difference in these outputs may be attributable to the fact that these tapes were formulated and coated for different applications. They could easily be reformulated for the crash recorder application.

The remaining incompatibility is that neither high temperature tape has a backcoating to provide for endless loop cartridge operation as does the 3M 156. ~~Graham Magnetics indicated that they do not plan to develop a backcoating for their product.~~ IITRI could develop a backcoating for the IITRI High Temperature tape using a similar binder as utilized in the oxide formulation.

3.3 Conclusion

Substantially improved environmental performance benefits are attainable by switching from tapes currently in use to either of the two high temperature tapes tested in this program. Minor incompatibilities between the high temperature tapes and those presently in use have been noted. It is recommended that a small developmental program be carried out at IITRI to reformulate the IITRI high temperature tape to remove the following incompatibilities:

1. Reproduce Signal Output

2. Lack of Lubricated Backside

The reproduce signal output may be increased easily using the same formulation by orienting the magnetic particles and by improving the dispersion of the pigment resin formulation. This improved processing would be coated at a thicker coating thickness much like 3M156 which would further increase the output.

A formulation consisting of high temperature polyimide, graphite and solvent could be prepared and backcoated on the Kapton[R] basefilm to provide for the lubricated backside necessary to ensure compatibility with 3M 156.

A program such as this is necessary to provide a tape which is completely compatible with 3M156. Such a tape could be directly replaced on the flight recorders in use in the majority of commercial aircraft in use today and would provide an increase in environmental operability from the present 200°F to over 800°F at minimal cost.

# APPENDIX A

## PROPOSED SPECIFICATION, TAPES, RECORDING SOUND, MAGNETIC OXIDE COATED, SEVERE ENVIRONMENT; DESIGNED FOR DIRECT REPLACEMENT IN EXISTING AIRCRAFT CRASH RECORDERS

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PROPOSED SPECIFICATION, TAPES, RECORDING, SOUND MAGNETIC OXIDE COATED, SEVERE ENVIRONMENT: DESIGNED FOR DIRECT REPLACEMENT IN EXISTING AIRCRAFT CRASH RECORDERS

1. SCOPE AND PROGRAM

This specification covers magnetic recording tape that is for use in audio logging crash recorders aboard aircraft. The tape must have the capability of withstanding environmental conditions as experienced in an aircraft crash, with post-impact fire. This specification outlines the minimum requirements for such a tape. In general, with the exception of the environmental constraints and tape life, this specification follows existing interim federal specification W-T-0070 promulgated by the Bureau of Ships, Department of the Navy, Washington, D. C.

2. This section not applicable at this time.

3. GENERAL REQUIREMENTS

3.1 Qualification

The recording tape furnished under this specification shall be a product which has been tested, and passed the qualification tests specified herein.

3.2 Component Parts

Reels and hubs of tape shall consist of individual rolls of tape wound on reels or hubs, as specified.

3.3 Materials

3.3.1 Tape

The tape, composed of a layer of magnetic material on a suitable backing material, shall have physical, magnetic, and other characteristics as specified in the individual detail specification.

3.3.2 Reels and Hubs

Unless otherwise specified in the contract or order, reels and hubs shall conform to W-R-00175 (NAVY-Ships).

3.4 Physical Requirements

3.4.1 Yield Strength

The yield strength of a particular class or type of tape, when tested as specified in 4.4.3, shall equal or exceed the value specified in the individual detail specification.

3.4.2 Shock Tensile Strength

The maximum energy absorption (shock tensile strength) of a particular class or type of tape, when tested as specified in 4.4.4, shall equal or exceed the value specified in the individual detail specification.

3.4.3 Elongation Under Stress

The elongation of a particular class or type of tape, when tested as specified in 4.4.5, shall not exceed the value specified in the individual detail specification.

3.4.4 Layer to Layer Adhesion

The tape shall show no sticking layer-to-layer adhesion, when tested as specified in 4.4.8. Layer-to-layer adhesion, commonly termed blocking, is defined as that property of a magnetic tape wherein one layer when held in close proximity to an adjacent layer, as when in a roll of tape, exhibits an adhesive nature and bonds itself to an adjacent layer so that free and smooth separation of the layers is difficult. In practice, the amount of adhesion may vary from a quantity which merely prevents adjacent layers from separating freely to the most severe condition in which the adhesion is so great that the magnetic coating is disengaged from the tape backing when the tape is unwound. Adhesion in any form is objectionable, since tape which displays even mild layer-to-layer adhesion may in time progress to the point where it is impossible to separate layers without destroying the tape.

3.4.5 Splices

There shall be no splices in any reel containing a nominal 1800 feet of tape or less.

3.5 Tape Dimensions

3.5.1 Length

The tape shall be supplied in minimum lengths on reels or hubs in accordance with W-R-00175 (NAVY-Ships) having nominal diameters in accordance with Table I, unless otherwise specified.

3.5.2 Width

Tape shall be supplied in widths in accordance with Table II as specified.

3.6 Composition

3.6.1 Inflammable Materials

Inflammable materials such as cellulose nitrate, which will ignite from a match flame and when so ignited will continue to burn in a still carbon dioxide atmoshpere, shall not be used.

Table I

TAPE LENGTH

| Nominal length (feet) | Minimum length (feet) | Nominal reel diameter (inches) | Nominal hub diameter (inches) |
|---|---|---|---|
| 150 | 155 | 3 | --- |
| 225 | 230 | 3 | --- |
| 300 | 305 | 4 | --- |
| 450 | 460 | 4 | --- |
| 600 | 610 | 5 | --- |
| 900 | 915 | 5 | --- |
| 1200 | 1215 | 7 | --- |
| 1800 | 1820 | 7 | --- |

Table II

TAPE WIDTH

| Nominal width (inch) | Dimension (inch) | Width tolerance (inch) |
|---|---|---|
| 1/4 | 0.246 | +0.002<br>∓ .000 |
| 1/2 | .500 | - .004<br>+ .000 |
| 3/4 | .750 | - .004<br>+ .000 |
| 1 | 1.000 | - .004 |

3.6.2 Toxic Compounds

The use of compounds which readily produce harmful toxic effects under the conditions normally encountered in government service will not be permitted.

3.7 Magnetic Requirements

3.7.1 Output

3.7.1.1 Sensitivity

The output of a particular class or type of tape at any point in a reel, when measured in accordance with 4.5.3.1.1, shall not vary from the standard output level by more than the value specified in the individual detail specification.

3.7.1.2 Frequency Response

The output at the specific test frequencies of a particular class or type of tape, when measured in accordance with 4.5.3.1.2, shall fall within the limits specified in the individual detail specification.

3.7.1.3 Distortion

The total harmonic distortion at the specific test record levels of a particular class or type of tape, when measured as specified in 4.5.3.3 and 4.5.3.1.1, shall not exceed the values specified in the individual detail specification.

3.7.1.4 Uniformity

The uniformity of the signal output at the specific test frequencies of a particular class or type of tape, when tested as specified in 4.5.3.2, shall be such that the maximum deviation from the maximum peak output does not exceed the value specified in the individual detail specification.

3.7.2 Signal to Direct Current (d.c.) Noise Ratio

The signal to d.c. noise ratio of a particular class or type of tape, when tested in accordance with 4.5.3.3, shall equal or exceed the value specified in the individual detail specification.

3.7.3 Instantaneous Non-Uniformity (Dropouts)

The total number of dropouts of a particular class or type of tape, when tested as specified in 4.5.3.4, shall not exceed the value specified in the individual detail specification.

3.7.4 Layer-to-Layer Signal Transfer

A signal resulting from layer-to-layer signal transfer for a particular class or type of tape, when measured as specified in 4.5.3.5, shall be below the signal level by at least the value specified in the individual detail specification. The correction factor specified in the individual detail specification shall adjust the layer-to-layer signal transfer value due to the oxide characteristics.

3.7.5 Ease of Erasure

An erase field of the specific test value shall effect a reduction in signal for a particular class or type of tape, when tested as specified in 4.5.3.6, of at least the value specified in the individual detail specification.

3.7.6 Frictional Vibration

The tape shall not produce squeal components of an audible nature during the magnetic tests. Frictional vibration, which in practice manifests itself as a squeal, is defined as the random frequency and amplitude modulation or both of a recorded signal which results when the tape passes over the guides and heads of a magnetic tape recorder. This results from the changing frictional components introduced between the tape, heads and guides as the tape travels past them.

3.8 Wind

The tape shall be wound on the reel or hub with the oxide surface inside (that is, facing the center of the hub).

3.9 Workmanship and General Examination

Rolls of tape shall be manufactured and processed in a careful and workmanlike manner, in accordance with good practice.

Tape shall be wound on the reels at a relatively constant tension leaving no individually loose or tight sections.

3.10 Detail Requirements for Individual Types of Tape

Detail requirements for individual types of tape shall be as specified in the applicable detail specification. In the event of any conflict between requirements of this specification and the detail specifications, the latter shall govern.

4. SAMPLING, INSPECTION AND TEST PROCEDURES

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the government. The government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Qualification Tests

Qualification tests shall be conducted at a laboratory satisfactory to the F.A.A. Qualification tests shall consist of the tests specified in 4.4, 4.5, 4.6, 5.1, 5.2 and 5.3.

4.3 This section not used at this time.

4.4 Physical Tests

4.4.1 Preliminary Conditioning

Preliminary conditioning of each reel or hub of tape will be required prior to qualification testing to relieve stresses and establish uniformity. Reels or hubs of tape shall be rewound under a tension of 8 ounces or less. The reels or hubs of tape shall then be conditioned at $125^{\circ} \pm 5^{\circ}$ F, 80 to 90 percent relative humidity (r.h.) for 2 hours. The tape shall then be removed from the oven and held in a room conditioned at $70^{\circ} \pm 5^{\circ}$F, 45 ± 5 percent r.h. for 2 hours. This temperature humidity cycle shall be repeated five times. Upon removal from the oven after the last heat cycle, the tape shall immediately be rewound a minimum of three times at a tension not exceeding 8 ounces. The tapes shall then be held in a room conditioned at $70^{\circ} \pm 5^{\circ}$F, 45 ± 5 percent r.h. for a minimum of 24 hours before any tests are made.

4.4.2 Test Conditions

Unless otherwise specified in the contract or order, all tests required by this specification shall be made at an ambient temperature of $70^{\circ} \pm 5^{\circ}$F and a relative humidity between 25 and 50 percent in a relativey dust free atmosphere.

4.4.3 Yield Strength

4.4.3.1 Apparatus

The vertical light capacity tensile tester, type 272, manufactured by Amthor Testing Instrument Company, Inc., contains all the necessary features for this test. The pulling speed of the machine is variable from 3 to 30 inches per minute, and there are three yield strength ranges, 0 to 1, 0 to 3, and 0 to 10 pounds. It is understood that standard 1-inch clamps can be specifically designed on request for use with recording tape. The above machine or equal will be satisfactory for this test.

4.4.3.2 Preparation of Sample

No special preparation of the sample is required, except as specified in 4.4.1.

4.4.3.3 Procedure

A strip of tape not less than 6 inches in length shall be clamped in jaws initially set 4 inches apart, and the stressing jaw shall then be displaced at a speed of 12 inches per minute until the specimen reaches the yield point. Not less than three specimens of a particular class or type of tape shall be tested. The arithmetic average of yield strength shall be reported as the yield point in pounds per 1/4 inch of tape width.

4.4.4 Shock Tensile Strength

4.4.4.1 Apparatus

The apparatus for the test shall be a pendulum-type slipperiness tester as specified in Bureau of Standards Research Paper RP1879 Volume 40 of May 1948. The mechanical heel is removed and replaced with a cylindrical pendulum bob of chrome plated brass 1-1/4 inch diameter and 1-1/4 inches long, threaded axially to receive the 1/2 inch - 20 thread of the pendulum arm. The brass pendulum bob shall be polished until the finish is equivalent to that specified as a General Electric Roughness "B" or better (8 microinches average peak to valley) and then chromium plated to a thickness of at least 0.001 inch according to standard plating procedures and buffed to a smoothness equal to the metal base. The weight of the entire pendulum assembly shall be 0.6 pounds with center of gravity 13-1/2 inches from the axis, and the distance from the axis to the portion of the bob which contacts the center line of the tape shall be 16-1/4 inches. To the slotted weights at the base of the apparatus is fastened a base-plate 1/4-inch thick, to which is attached a clamping assembly as shown on Figures 1 through 8.

4.4.4.2 Preparation of Samples

Samples shall be prepared as specified in 4.4.1. Lengths of sample tape sufficient for this test shall be unwound from the reels and placed in 45 ± 5 percent r.h., 70 ± 5° F atmosphere without bends or kinks, and allowed to remain for at least 24 hours before test.

4.4.4.3 Procedure

The sample of tape 12 ± 1/16 inches in length shall be positioned so that a free loop with the magnetic side inward is in the path of the cylindrical bob. The tape sample shall be securely clamped in the apparatus and the pendulum arm shall be raised until it makes an angle with the vertical of 83 degrees (corresponding to a potential energy of 0.59 foot pounds). The pendulum shall then be released smoothly and shall be allowed to strike the free loop of the tape, break it and swing past to indicate the residual energy of the pendulum. The difference between the initial and the residual energy of the pendulum is the energy abosrbed by the specimen in breaking.

4.4.5 Elongation under Stress

4.4.5.1 Apparatus

The apparatus for this test shall consist of standard means of measuring length, positive nonslipping clamping devices, a 50 gram weight and weights as specified in the individual detail specification.

4.4.5.2 Preparation of Samples

Samples shall be prepared as specified in 4.4.1. Samples at least 24 inches long shall be clamped so as to hang in the test area ($70^{o} \pm 5^{o}$F, 45 ± 5 percent r.h.) for at least 24 hours under no externally applied stress before tests are begun.

4.4.5.3 Procedure

Before any weight is hung on the samples, a mark shall be made approximately 20 inches from the point of clamping to measure the elongation and recovery of the sample. The distance between the mark and clamping point shall be measured accurately to the nearest 0.01 of an inch with an applied tension of 50 grams. This distance shall be taken as the base distance for calculation of residual elongation. When the measurement of the base distance has been made, the test shall begin. The test weight, as specified in the individual detail specification, shall be attached to the tape below the mark at zero time and allowed to hang undistrubed for exactly 180 minutes ± 30 seconds, at which time the weight shall be removed from the tape. The tape shall be allowed to hang under its own weight for an additional 180 minutes ± 30 seconds. The distance between the mark and the point of clamping shall then be measured to the nearest 0.01 inch with an applied tension of 50 grams. The difference between the base distance and the final distance shall be expressed as a percent of the base distance to determine compliance with 3.4.3.

4.4.6 Humidity Stability (cupping)

4.4.6.1 Apparatus

The apparatus for this test shall consist of the following: (If a controlled temperature and humidity room is available, this may be used in place of the chamber).

4.4.6.1.1 Chamber

The humidity chamber shall be of materials which are non-reactive to water vapor and potassium chloride solution and shall be constructed so that all joints are sealed tight when the chamber is closed. It shall consist of two separate compartments each approximately 11 by 13 by 7 inches. The front and back sides of the compartments shall be of a transparent material such as glass. The trays used to hold the chemicals inside the chamber shall measure approximately 10 by 10 by 4 inches and shall be made from aluminum, glass or any nonreactive material. The trays shall be provided with removable perforated aluminum cover plates to permit placing tape holders above the conditioning chemicals with minimum interference with free air circulation. Means shall be provided for circulation of air within each compartment with a velocity of at least 20 feet per minute across both the conditioning chemicals and the tape holders.

4.4.6.1.2 Tape Holders

Each tape holder shall, when filled, clamp the tape along its longitudinal axis and shall prevent any movement of the longitudinal axis of the tape by positively contacting it beginning at the end where the cupping is to be measured and continuing at least 1 inch along the tape length. The holder shall raise the tape at least 1/8 inch above the holder base plate and shall be separated from the adjacent tape holder by at least 5/8 inch, thus insuring that there will be no interference to cupping in either direction. For example, this may be accomplished by constructing the holder from two pieces of straight, rust or corrosion-resistant wire, the bottom piece being 1/3 inch in diameter and the top piece being 1/16 inch in diameter, 1-1/2 inches in length which are soldered or brazed together at the front tips, and then brazed onto a base plate of noncorrosive material. When the tape holders are in place in the chamber compartment and with tapes inserted for measurement, the longitudinal axis of the tapes shall be substantially horizontal.

4.4.6.1.3 Measuring Instrument and Illumination

The measuring device shall be any optical system with a magnification of from 5 to 25 times, having at least one crosshair which can be referred to a clinometer or goniometer so as to measure the angle between the crosshair and a reference line, and having a focal length such that it can be focused on the near end of a tape when the tape is mounted in the chamber and the measuring device is placed in front of the chamber. A source of light shall be placed behind the chamber during measurement to outline the tapes when viewed through the measuring instrument.

4.4.6.2 Preparation of a Sample

No special preparation of the samples is needed, except as specified in 4.4.1.

4.4.6.3 Procedure

The test procedures shall be as follows:

(a) Prior to conditioning the samples, the initial tape cupping shall be measured on each test specimen. The measurement on each specimen is performed by viewing the ends of the specimen through the measuring instrument so as to measure the angle formed by the conjunction of lines constructed perpendicular to the edges of the viewed tape end. Local irregularities shall be averaged when setting the crosshair for these measurements.

(b) When using a two compartment chamber for conditioning the samples, one chamber shall be desiccant and the other chamber shall be humidifying. The desiccant chamber shall contain a desiccant anhydrous calcium chloride with indicating "Drierite" in the ration 3 to 1. The humidified chamber shall have a saturated solution (plus an excess) of potassium chloride in distilled water as the humidifying agent. The chambers containing the conditioning media shall be closed and the air circulated for at least 12 hours immediately preceding the insertion of the tapes to insure equilibrium. The test shall be run at temperature of 90° ± 5F. in both cabinets. The humidity conditions shall be 90 ± 5 percent in the wet chamber and 15 ± 5 percent in the dry chamber. If a two compartment chamber is used, a 6 inch length of tape shall be selected and cut into two 3 inch pieces with scissors (not a razor blade). These shall be mounted as specified in 4.4.6.1.2 with the backing side down on two separate holders, one to be placed in the desiccant chamber and the other in the humidifying chamber, so that the measured ends are those made by the scissors cut in each case. The tape holders containing the tape specimen shall be placed in their respective sections. The compartments shall be closed, and the air shall be made to circulate for at least 16 hours before the measurements are made. (This shall apply to tests in a humidity room as well). At the end of conditioning the differential cupping, the arithmetical difference in degrees between the angle measured on the desiccated tape and the angle measured in the same manner on the humidified tape, will be one of the criteria for acceptance or rejection of such tape. Since this test is designed to measure the effect of differential cupping, local irregularities shall be averaged when setting the crosshair for these measurements.

(c) Neither the "initial" cupping, "differential" cupping nor the cupping under any one condition (wet or dry chamber) shall fail to meet the requirements specified in 3.4.4.

4.4.7 Fungus Resistance

Not applicable.

4.4.8 Layer-to-Layer Adhesion

4.4.8.1 Apparatus

The apparatus for this test shall consist of 1000 gram weight and a 1/2 inch diameter hollow tube. The tube shall be made of a nonoxidizing metal such as brass or corrosion resisting steel 1/2 inch in diameter and 4 inches in length, and shall weigh not less than 15 grams nor more than 30 grams. The tube shall be capable of being mounted in bearings so that it may be rotated freely around its central axis and easily removed from the bearings.

4.4.8.2 Preparation of Sample

No special preparation of the sample is required, except as specified in 4.4.1.

4.4.8.3 Procedure

The test procedures shall be as follows:

(a) The 3 foot sample length of tape shall be featured at one end, magnetic side down, to the 1/2 inch diameter hollow tube with a nonoozing adhesive material. The tube shall then be mounted in the bearings such that the tape shall hang free below the tube.

(b) Attached to the free end of the tape shall be the 1000 gram weight. A small strip of double-coated adhesive tape shall be affixed to the magnetic side of the tape one inch above the weight. The tube shall then be slowly and uniformly rotated so that the tape, held in tension by the weight, winds uniformly around the tube into a compact and even roll. The double-coated tape when wound into the test roll acts to secure the roll and prevent its unwinding when the weight is removed.

(c) The tube supporting the rolled tape shall be removed from the winding setup and subjected to a heat and humidity cycle in which the first 30 min shall be at 800°F and 50 ± 5% r.h., while the final 30 min shall be at 800°F dry heat (less than 5% r.h.). This cycle may be accomplished in any manner suitable to the testing technicians so long as the conditions stated are met. During the humidification and dry heat cycle, provisions shall be made so that the air surrounding the tube is constantly circulated to assure uniformity of conditions throughout the test area. At the end of the dry heat cycle, the rod shall be removed from the conditioned area and allowed to come to equilibrium with room conditions approximately 70°F at 45% r.h.

(d) To evaluate the tape for layer-to-layer adhesion, the end of the roll on the rod shall be carefully opened and the double coated tab shall be removed. The rod shall then be held between the thumb and fingers and the untabbed tape shall be observed to note if the first two or three layers loosen up of their own accord; if this occurs, there is obviously no adhesion and the tape has passed the test. If no loosening or very little loosening of the outermost layers is observed, the free end of the tape shall be unwound slowly until 9 inches has been unwound. The free end shall then be allowed to hang and the tape shall be observed to see if it will unwind itself. If it will not unwind unaided, the rod, with the tape hanging freely, shall be slowly rotated in the direction of tape unwind. If the tape adheres to itself and refuses to begin to unwind after the rod has been rotated through one-fourth revolution or 90 degrees, it shall be considered to have failed the test. After the rotation test has been made, the free end of the tape shall be held and the rod allowed to fall, thereby unwinding the tape. The unwound tape shall be checked for evidence of coating delamination and in this way the severity of adhesion is established. Any tape which will not self-unwind after rotating the rod 90 degrees or which shows any delamination except in the 2 inches nearest the rod shall be considered as having failed this test.

4.4.9 Anchorage

A visual examination shall be made of the tape after completion of all tests to determine suitable anchorage.

4.4.10 Physical Parameters

All physical parameters shall be measured to determine conformance to the physical requirements specified herein and in the individual detail specification.

4.5 Magnetic Tests

4.5.1 Definitions

4.5.1.1 Standard Reference Tape

A typical production sample of 3M Type 111 Tape will suffice as standard for this specification.

4.5.1.2 Secondary Standard Tape

Not applicable.

4.5.1.3 Operating Bias Current

Operating bias current is that bias current through the recording head which will give peak output from the standard reference tape at maximum record level. Operating bias current is set using the standard reference tape. (see 4.5.1.1).

4.5.1.4 Recording Levels

4.5.1.4.1 Maximum Recording Level

The maximum recording level is that input level which in conjunction with operating bias current will produce a permanent induction in the Standard Reference Tape such that on playback of a 1000 cps. signal, the output signal will have 3 percent total harmonic distortion. Maximum recording level is set in conjunction with operating bias current using the standard reference tape (see 4.5.1.1).

4.5.1.4.2 Standard Recording Level

The standard recording level is 15 db below the maximum recording level.

4.5.1.5 Output Levels

4.5.1.5.1 Maximum Output Level

The maximum output level is that r.m.s. output voltage measured across a 600-ohm load on playback of a 1000 c.p.s. signal recorded on the Standard Reference Tape at maximum recording level with operating bias current.

4.5.1.5.2 Standard Output Level

The standard output level is that r.m.s. output voltage measured across a 600-ohm load on playback of a 1000 c.p.s. signal recorded on the Standard Reference Tape at standard recording level with operating bias current.

4.5.2 Test Equipment

4.5.2.1 Standard Reference Recorder

For the tests specified in 4.5.3, a standard reference magnetic tape recorder (hereinafter called "reference recorder") shall be used. The reference recorder shall have the following minimum features.

(a) The recorder shall provide a tape speed of 7.5 inches per second ± 0.5 percent.

(b) The frequency response shall be flat to within plus or minus 2 db over the range 50 to 7500 c.p.s. and plus or minus 4 db over the range 50 to 10,000 c.p.s. at a tape speed of 7.5 inches per second using the standard reference tape (see 4.5.1.1)

(c) The total harmonic distortion introduced by amplifiers and heads shall not exceed 0.5 percent r.m.s. at all levels and frequencies used in the magnetic tests.

(d) The overall signal-to-noise ratio shall be 60 db or higher. By definition, the overall signal-to-noise ratio is the ratio of maximum output level to the total unweighted playback noise after erasure of a signal recorded at maximum recording level and in the absence of a new signal. Thus, bias and erase noises are included as well as the playback and record amplifier noises. All frequencies between 50 and 15,000 c.p.s. shall be measured.

(e) The "flutter" and "wow" components shall be less than 0.2 percent r.m.s. at a speed of 7.5 inches per second, measuring all components below 200 c.p.s.

(f) The recorded track width shall be the full width of tape, 0.250 inch.

(g) The erase signal shall be kilocyles (kc.) or higher. The signal shall be such as to reduce the level of a signal (recorded at maximum recording level) at least 65 db.

(h) The bias frequency shall be 60 kc. or higher, and adjustable in amplitude.

(i) The pre-equalization curve of the reference recorder shall be as shown on Figure 9.

(j) The post equalization curve of the reference recorder shall be within the limits shown on Figure 10, and such that the overall response is in accordance with 4.5.2.1(b).

(k) There shall be a separate head for each of the functions: erase, record, and playback, and the reference recorder shall be arranged so that playback may be accomplished simultaneously with record.

(l) The reference recorder shall accommodate all reels and hubs as specified in 3.3.2 except 14-inch reels.

(m) A professional type commercial recorder (such as Ampex 300 or equivalent) which conforms to the requirements specified herein may be used for the applicable tests specified in 4.5.3.

(n) Before tests, the heads of the reference recorder shall be thoroughly demagnetized and the record and playback heads shall be aligned for azimuthal orientaiton (90 degrees) of their respective gaps. Before tests, the recorder shall have had the equivalent of at least 20,000 feet of tape passing the heads under recorder or reproduce conditions.

4.5.2.2 Standard Recorder for Dropout Counting

Note applicable at this time.

4.5.3 Test Setup

The test setup for the reference recroder prior to performing the magnetic tests shall be as follows:

(a) All magnetic tests shall be conducted at a tape speed of 7.5 inches per second ±0.5 percent and with a 0.250 inch track width using the reference recorder specified in 4.5.2.1.

(b) Prior to testing the heads of the reference recorder it shall be thoroughly cleaned and demagnetized, and the record and playback heads shall be adjusted for correct azimuthal orientaiton. The tension of the reference recorder shall be measured to determine that the recorder is in proper adjustment.

(c) The maximum recording level and operating bias current shall be established for the reference recorder using the standard tape (see 4.5.1.1). For the magnetic measurements, the tape samples shall not require any preliminary conditioning.

4.5.3.1 Output

4.5.3.1.1 Sensitivity

The standard output level (see 4.5.1.5.2) shall be established to calibrate the reference recorder for the sensitivity measurement. A 1000 c.p.s. signal shall be recorded on the tape at the standard record level and at operating bias current. This tape shall be played back and the r.m.s. output voltage of the playback amplifier of the recorder measured in db across a 600-ohm load. Correction shall be made for the response of the reference recorder with the standard reference tape at operating bias current. Total harmonic distortion also shall be measured.

4.5.3.1.2 Frequency Response

The procedure specified in 4.5.3.1.1 shall be repeated at all frequencies specified in the individual detail specification. The output of each frequency shall be normalized to the 1000 c.p.s. output and expressed in db. Correction shall be made for the response of the reference recorder with the standard reference tape at opeating bias current.

4.5.3.2 Uniformity

The frequencies, as specified in the individual detail specification, shall be recorded at standard recording level and with operating bias current. On playback, the output voltage variations shall be measured by means of a linear recording oscillograph having a response which is uniform to at least 100 c.p.s. The tape uniformity, over a tape length of at least 50 feet, shall be measured by determining the peak variation in output as a percentage of maximum peak output.

4.5.3.3 Signal to d.c. Noise Ratio

A 1000 c.p.s. signal shall be recorded at the maximum record level with operating bias current. The tape shall be played back, and the r.m.s. voltage output of the playback amplifier of the reference recorder measured in db across a 600-ohm load using a 250-c.p.s highpass filter. This value shall be taken as the signal level. Total harmonic distortion shall also be measured. The tape shall then be externally erased, and a d.c. supplied to the record head equal to the r.m.s. value of the audio current at maximum record level. Under these conditions the tape shall be recorded on the reference recorder with operating bias current. The r.m.s. output voltage on playback measured as specified herein, shall be taken as the d.c. noise level. The signal to d.c. noise ratio is the value in db of the signal level minus the value of the d.c. noise level.

4.5.3.4 Instantaneous Non-Uniformity (dropouts)

Not applicable at this time.

4.5.3.5 Layer-to-Layer Signal Transfer

The tape shall be externally erased. With the reference recorder opeating at maximum record level with ~~opeatinb~~ operating bias and with erase head operating, ~~the~~ ten layers of tape shall be recorded with no signal input to the reference recorder and shall be wound on a reel or hub classified as ER-250-PC or EH 250-RC in accordance with W-R-00175 (Navy-Ships). The record level shall be increased to maximum recording level at operating bias current with a 1000 c.p.s. signal and one additional layer recorded and wound on the reel or hub. The record level shall be ~~reutnred~~ returned to zero and ten additional layers shall be recorded and wound on the reel or hub. The recorded tape shall be conditioned at a temperature of 150° F for a peirod of 4 hours. The tape shall then be played back and and the output of pass filter and the output of the filter shall be meausred across a 600 ohm load. The level of the recorded signal and the level of the signal resulting from the signal transfer shall be measured.

4.5.3.6 Ease of Erasure

The tape shall be externally erased. A frequency of 1000 c.p.s. shall be recorded at maximum record level with operating bias and with erase head operatin g. The tape shall then be conditioned at a temperature of 150° F for 4 hours, and shall be played back with the record and erase heads disconnected to cut off the erase, bias, and record currents. The output of the playback amplifier shall be connected to a 1000 c.p.s. ? band-pass filter and the output of the filter shall be measured across a 600 ohm load. The tape shall be passed through a solenoidal coil producing a 60 c.p.s. a.c. field of 1000 oersteds (peak value) after which the level of the residual signal on playback shall be measured through a 1000 c.p.s.? band-pass filter. The difference between the recorded signal level and the residual signal level is the effective reduction in signal or ease of erasure.

4.6 General Examination

Reel or hubs of tape shall be examined to determine that the tape has a generally smooth unblemished appearance with cleanly slit edges. The wind of the tape on the reel or hub shall be examined to determine that it is uniform, there shall be no marked looseness of turns within the reel or hub or evidence of undue stresses as shown by gathering of tape so that wind is other than circular.

## 5. DETAIL REQUIREMENT SECTION

### 5.1 Backing Requirements

The tape backing requirements shall be as specified in Table 3.

Table 3

BACKING REQUIREMENTS

| Characteristics | Backing and thickness<br>Polyester 1.0 mil | Units |
|---|---|---|
| Yield strength | 3.7 | Pounds |
| Shock tensile strength | 0.58 | Foot-pounds |
| Elongation under stress (see note) | 0.50 | Percent |
| Humidity stability | 5 | Degrees |
| Layer-to-layer signal transfer (see Table II) | 40 | Decibels |

Note: A 2-1/2 pound weight shall be used to apply the measurement load on the tape samples.

### 5.2 Oxide Requirements

The tape oxide requirements shall be as specified in Table 4.

Table 4

OXIDE REQUIREMENTS

| Characteristic | Oxide Characteristic "B" | Units |
|---|---|---|
| Sensitivity | ± 2 | Decibels |
| Frequency response at: | | |
| 200 c.p.s. | 0 ± 2 | Decibels |
| 5,000 c.p.s. | 2 ± 2 | Decibels |
| 8,000 c.p.s. | 2 - 2 (No + limit) | Decibels |
| Distortion at: | | |
| Standard record level | 1.0 | Percent |
| Maximum record level | 4.0 | Percent |
| Uniformity at: | | |
| 1,000 c.p.s. | 25 | Percent |
| 5,000 c.p.s. | 40 | Percent |
| Bias variation | +0, -5 | Percent |
| Signal-to-d.c. noise ratio | 55 | Decibels |
| Correction factor | | |
| (layer-to-layer signal transfer) | 0 | Decibels |
| Ease of erasure | 50 | Decibels |

### 5.3 Environmental Test Requirements

#### 5.3.1 Sample Preparation

Test specimen shall be recorded with standard record level (Ref. Section 4.5.1.4.2) with a 4,000 c.p.s. signal on the standard reference recorder (Ref. Section 4.5.2.1) at a speed of 7.5 i.p.s. Prior to the severe environment conditioning. The recorded tape shall be cut into 100 foot specimens and each wound under a tension of 4 oz onto a NAB type metal hub.

#### 5.3.2 Low Temperature Environmental Requirement

The specimens shall be subjected to an ambient temperature of minus 25 degrees centigrade (-13°F) for 5 hours. They shall then be returned to room temperature for a period of 5 hours and subjected for compliance with Section 5.1 and 5.2 of this specification.

#### 5.3.3 Elevated Temperature Environmental Requirement

The specimens shall be exposed to an ambient temperature of 70° C (158°F) for 24 hours, followed by exposure to -25°C (-13°F) for 24 hours, followed immediately be exposure to room temperature for not more than 3 hours. There shall be no evidence of damage as a result of exposure to these conditions and shall meet all requirements as indicated in Section 5.1 and 5.2 of this specification

#### 5.3.4 Severe Temperature Environmental Requirement

The prerecorded tape and supply reel shall be placed in a 4-inch diameter by 1/2 deep stainless steel closed container.

The container with test specimen enclosed will be placed in an oven and subjected to a temperature of 466.6°C (800°F) for a period of 45 minutes.

If the tape fails at 800°F, but shows promise of success at a lower temperature, additional tests will be performed at temperatures of 700°C and 600°F.

The specimens shall then be permitted to cool under normal conditions to room temperature, then be subject to playback, with no more than a 2 db change from the pretest measurements and meet all requirements as indicated in Section 5.1 and 5.2 of this specification.

5.3.5 Humidity Environment

The specimens shall be placed in an environmental chamber at 70 ± 2°C (158 ± 5°F) and a relative humidity of 95 ± 5% for six hours. The heat shall then be changed to 38°C (100°F) and remain for 18 hours. This complete cycle should be repeated 10 times. The test specimens shall be tested and be determined to be in compliance with Section 5.1 and 5.2 of this specification.

5.3.6 Water Immersion

The specimens shall be immersed in sea water for 30 days. The samples should be removed at the end of this period and washed with fresh water and air dried. The test specimens shall be tested and be determined to be in compliance with Section 5.1 and 5.2 of this specification.

5.3.7 Hydraulic Fluid Exposure

The specimens shall be immersed in Skydrol 500-type hydraulic fluid for a period of 120 hours. They shall then be removed and placed in an oven at 72°C (161.6°F) for 120 hours. The specimens shall then be cooled under normal atmospheric conditions. The specimens shall then be washed in a bath of suitable solvent to remove Skyahol 500 and air dried. The test specimens shall be tested and be determined to be in compliance with Section 5.1 and 5.2 of this specification.

5.3.8 Tape Life Test

The specimens shall be capable of 1,000,000 passes on a standard 4' loop test machine fitted with an aluminum head, 4.0z tension and 30° total head wrap without producing significant amounts of oxide debris at 30 i.p.s. Following this test the specimens shall be tested and determined to be in compliance with Sections 5.1 and 5.2 of this specification. Headwear shall be measured and determined to be less than 70 microinches as measured by a "Proficorder" or equivalent.

5.3.9 Severe Temperature Layer-to-Layer Adhesion

Test conditions described in Sections 3.4.4 and 4.4.8 (including tests 4.4.8.1 through 4.4.8.3) shall be met after exposure to a temperature of 800°F for the period indicated.

APPENDIX B

WORK STATEMENT

## 1. SELECTED TESTS

### 1.1 Test Procedures

All tests performed in this section will be performed in accordance with the "Proposed Specification, Tapes, Recording, Sound, Magnetic Oxide Coated, Severe Environment; Designed for Direct Replacement in Existing Aircraft Crash Recorders." A copy of this proposed specification is included in Appendix A of this proposal.

### 1.2 Basic Operational Tests

#### 1.2.1 Scope

The purpose of these tests is to determine basic compatibility with existing mylar based tapes utilized in flight recorders today. These tests are proposed to ensure that any selected high temperature tape will be usable on existing flight recorder hardware. This will ensure minimum retrofit expense for airlines for compliance with any subsequently promulgated flight standard in this area.

#### 1.2.2 Tests to be Performed (Appendix A)

All tapes shall meet the requirements of Section 5.1 and 5.2 as follows and have the characteristics shown in Tables 1 and 2.

Table 1

BACKING REQUIREMENTS

| Characteristics | Backing and thickness<br>Polyester<br>1.0 mil | Units |
|---|---|---|
| Yield strength | 3.7 | Pounds |
| Shock tensile strength | 0.58 | Foot-pounds |
| Elongation under stress (see note) | 0.50 | Percent |
| Humidity stability | 5 | Degrees |
| Layer-to-layer signal transfer (see Table II) | 40 | Decibels |

Note: A 2-1/2 pound weight shall be used to apply the measurement load on the tape samples.

Table 2

OXIDE REQUIREMENTS

| Characteristic | Oxide Characteristic "B" | Units |
|---|---|---|
| Sensitivity | ± 2 | Decibels |
| Frequency response at: | | |
| 200 c.p.s. | 0 ± 2 | Decibels |
| 5,000 c.p.s. | 2 ± 2 | Decibels |
| 8,000 c.p.s. | 2 - 2 (No + limit) | Decibels |
| Distortion at: | | |
| Standard record level | 1.0 | Percent |
| Maximum record level | 4.0 | Percent |
| Uniformity at: | | |
| 1,000 c.p.s. | 25 | Percent |
| 5,000 c.p.s. | 40 | Percent |
| Bias variation | +0, -5 | Percent |
| Signal-to-d.c. noise ratio | 55 | Decibels |
| Correction factor | | |
| (layer-to-layer signal transfer) | 0 | Decibels |
| Ease of erasure | 50 | Decibels |

(a) Magnetic Requirements

(1) Sensitivity (3.7.1.1 and 4.5.3.1.1)

The output of a particular class or type of tape at any point in a reel, when measured in accordance with 4.5.3.1.1, shall not vary from the standard output level by more than the value specified in the individual detail specification.

The standard output level (see 4.5.1.5.2) shall be established to calibrate the reference recorder for the sensitivity measurement. A 1000 c.p.s. signal shall be recorded on the tape at the standard record level and at operating bias current. This tape shall be played back and the r.m.s. output voltage of the playback amplifier of the recorder measured in db across a 600-ohm load. Correction shall be made for the response of the reference recorder with the standard reference tape at operating bias current. Total harmonic distortion also shall be measured.

(2) Frequency Response (3.7.1.2 and 4.5.3.1.2)

The output at the specific test frequencies of a particular class or type of tape, when measured in accordance with 4.5.3.1.2, shall fall within the limits specified in the individual detail specification.

The procedure specified in 4.5.3.1.1 shall be repeated at all frequencies specified in the individual detail specification The output of each frequency shall be normalized to the 1000 c.p.s. output and expressed in db. Correction shall be made for the response of the reference recorder with the secondary standard reference tape at operating bias current.

(3) Distortion (3.7.1.3, 4.5.3.3 and 4.5.3.1.1)

The total harmonic distortion at the specific test record levels of a particular class or type of tape, when measured as specified in 4.5.3.3 and 4.5.3.1.1, shall not exceed the values specified in the individual detail specification.

A 1000 c.p.s. signal shall be recorded at the maximum record level with operating bias current. The tape shall be played back, and the r.m.s. voltage output of the playback amplifier of the reference recorder measured in db across a 600-ohm load using a 250 c.p.s. highpass filter. This value shall be taken as the signal level. Total harmonic distortion shall also be measured. The tape shall then be externally erased, and a d.c. supplied to the record head equal to the r.m.s. value of the audio current at maximum record level. Under these conditions the tape shall be recorded on the reference recorder with operating bias current. The r.m.s. output voltage on playback measured as specified herein, shall be taken as the d.c. noise level. The signal to d.c. noise ratio is the value in db of the signal level minus the value of the d.c. noise level.

The standard output level (see 4.5.1.5.2) shall be established to calibrate the reference recorder for the sensitivity measurement. A 1000 c.p.s. signal shall be recorded on the tape at the standard record level and at operating bias current. This tape shall be played back and the r.m.s. output voltage of the playback amplifier of the recorder measured in db across a 600-ohm load. Correction shall be made for the response of the reference recorder with the standard reference tape at operating bias current. Total harmoic distortion also shall be measured.

(4) Uniformity (3.7.1.4 and 4.5.3.2)

The uniformity of the signal output at the specific test frequencies of a particular class or type of tape, when tested as specified in 4.5.3.2, shall be such that the maximum deviation from the maximum peak output does not exceed the value specified in the individual detail specification.

The frequencies, as specified in the individual detail specification, shall be recorded at standard recording level and with operating bias current. On playback, the output voltage variations shall be measured by means of a linear recording oscillograph having a response which is uniform to at least 100 c.p.s. The tape uniformity, over a tape length of at leat 50 feet, shall be measured by determining the peak variation in output as a percentage of maximum peak output.

(5) Signal to DC Noise Ratio (3.7.2 and 4.5.3.3)

The signal to d.c. noise ratio of a particular class or type of tape, when tested in accordance with 4.5.3.3, shall equal or exceed the value specified in the individual detail specification.

A 1000 c.p.s. signal shall be recorded at the maximum record level with operating bias current. The tape shall be played back, and the r.m.s. voltage output of the playback amplifier of the reference recorder measured in db across a 600-ohm load using a 250-c.p.s. highpass filter. This value shall be taken as the signal level. Total harmonic distortion shall also be measured. The tape shall then be externally erased, and d.c. supplied to the record head equal to the r.m.s. value of the audio current at maximum record level. Under these conditions the tape shall be recorded on the reference recorder with operating bias current. The r.m.s. output voltage on playback measured as specified herein, shall be taken as the d.c. noise level. The signal to d.c. noise ratio is the value in db of the signal level minus the value of the d.c. noise level.

(6) Frictional Vibration (3.7.6)

The tape shall not produce squeal components of an audible nature during the magnetic tests. Frictional vibration, which in practice manifests itself as a squeal, is defined as the random frequency and amplitude modulation or both of a recorded signal which results when the tape passes over the guides and heads of a magnetic tape recorder. This results from the changing frictional components introduced between the tape, heads and guides as the tape travels past them.

(7) Wind (3.8)

The tape shall be wound on the reel or hub with the oxide surface inside (that is, facing the center of the hub).

(8) Workmanship and General Examination (3.9)

Rolls of tape shall be manufactured and processed in a careful and workmanlike manner, in accordance with good practice. Tape shall be wound on the reels at a relatively constant tension leaving no individually loose or tight sections.

(9) Length (3.5.1)

The tape shall be supplied in minimum lengths on reels or hubs in accordance with W-R-00175 (NAVY-Ships) having nominal diameters in accordance with Table I, unless otherwise specified.

(10) Width (3.5.2)

Tape shall be supplied in widths in accordance with Table II as specified.

(c) Tape Life and Head Wear Performance Requirements

The specimens shall be capable of 1,000,000 passes on a standard 4' loop test machine fitted with an aluminum head, 4.0z tension and 30$^{o}$ total head wrap without producing significant amounts of oxide debris at 30 i.p.s. Following this test the specimens shall be tested and determined to be in compliance with Sections 5.1 and 5.2 of this specification. Headwear shall be measured and determined to be less than 70 microinches as measured by a "Proficorder" or equivalent.