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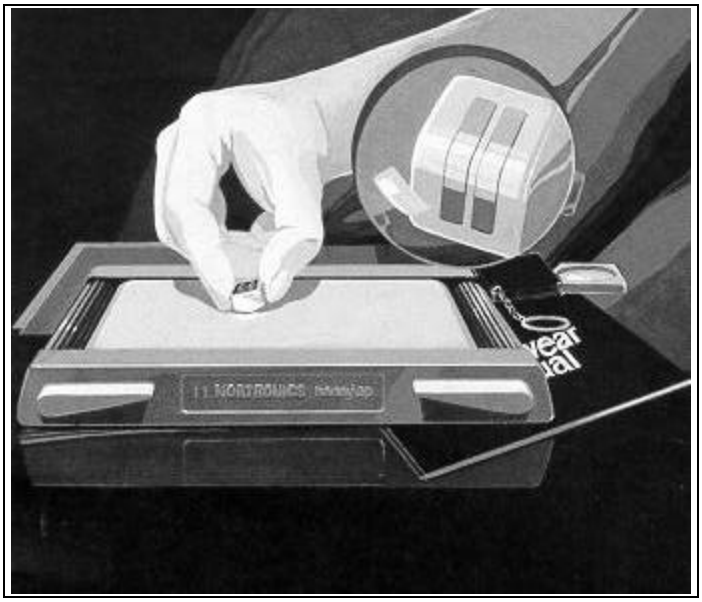

Head-wear Manual

includes instructions for use of **handylap** *Magnetic Head relapping kit*

Table of Contents

1. MAGNETIC HEAD WEAR FACTORS 3
1.1 Introduction 3
1.2 Head Construction 3
1.3 The Effect of Wear 4
1.4 Wear Patterns 4
1.5 Edge Slots 5
1.6 Spacing Losses 5
1.7 Reducing Head Wear 5
1.8 Head Relapping 6
1.9 The Effect of Tape on Head Wear 6
1.10 Long Wear Heads 7

2. QM-707 HANDYLAP™ - INSTRUCTIONS 8
2.1 Kit Contents 8
2.2 Description 8
2.3 Lapping Procedure 8
2.3.1 Worn Out Heads 9
2.3.2 Cleanliness 9
2.3.3 Water 9
2.3.4 Loading the Abrasive Sheet 9
2.3.5 Coarse Lapping 10
2.3.6 Medium and Fine Lapping 12
2.3.7 Worn Out Heads 13
2.4 Bare Bones Lapping Kit 14

Nortronics gratefully acknowledges the contribution of J. F. Dundovic to the contents of this book. The basis for that which appears herein was presented to the Audio Engineering Society at its 54th Convention on May 5, 1976 and also appeared in the October 1976 issue of the Journal of the Audio Engineering Society.

This reprint of the original Nortronics document contains additional information not found in the original 1977 document. Specifically, the new information is Section 2.4, Bare Bones Lapping Kit. Thanks again to Joe Dundovic for this information.

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1. MAGNETIC HEAD WEAR FACTORS

1.1 Introduction

All magnetic heads wear out eventually due to the abrasive action of the oxide surface of magnetic tape as it passes over the face of the head. As wear progresses, the partially-worn head frequently causes reproduction and/or recording problems. An examination of the head wear process requires answers to the following questions:

1 How does head wear affect performances

2 How can head wear be reduced?

3 At what point in the process should a worn head be relapped?

4 What conditions indicate that a head is fully worn out and should be replaced?

The material to follow will describe the conditions and factors that answer the four key questions above.

1.2 Head Construction

A typical **Record** or **Reproduce** head including core structure, coil and gap is detailed in Figure 1 . A magnified view of the gap area is also shown (in cross-section view) along with the two mating core tips, the gap spacer and the tape riding in contact with the head face at the gap. The thickness of the gap spacer determines gap length, and the value selected depends upon whether the head is to be used for recording or playback and the tape speed to be used. Cores are Usually fabricated from a highly-permeable magnetic material such as Hi-Mu 80, Mu-Metal or Permalloy. Other core materials are also used in head construction.

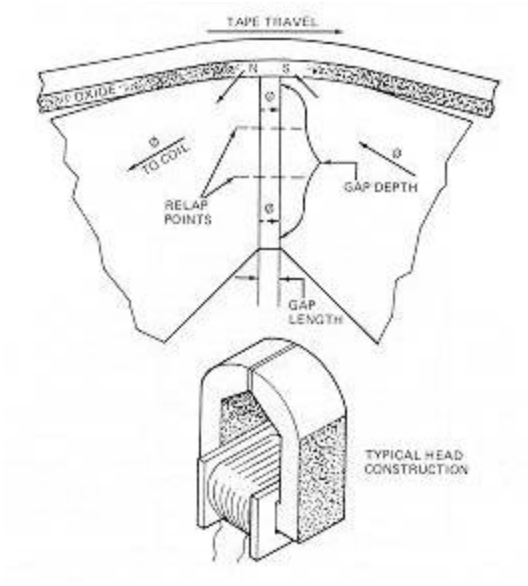


Figure 1. Head Gap

Gap depth - the distance from the head face to the bottom of the pole tip - effectively determines the amount of wear metal available. While it may appear that a very large gap depth is desirable in order to attain long head life, this is deceptive. As a practical matter, the actual gap depth is a **compromise between reasonable head performance and wear life.**

Excessive gap depth will produce an insensitive head with poor playback and record performance. This is due to the shunting effect of the gap, causing some of the flux to bypass rather than to flow around the core structure and through the coil. Typical gap depths run 16-22 mils (400-500 micrometers).

1.3 The Effect of Wear

As a head wears, the gap depth diminishes, causing the head characteristics to change as shown in Figure 2.

The two mating pole tips and the gap spacer are illustrated rotated 90 degrees from the view of Figure 1. As the head wears away from the original tape contact face shown at the left, playback sensitivity will vary as shown in the graph portion of Figure 2, gradually increasing in output as the gap depth decreases. When wear reaches to the bottom of the pole tip, and the gap begins to widen, the playback output will drop sharply, particularly at higher audio frequencies. This condition best characterizes the fully worn out play head that should be replaced.

The Record head will likewise become sensitive to bias current as head wear progresses, requiring less bias for peak output. Thus, periodic adjustments of record head peak bias will be required to prevent dropping high frequency response due to overbiasing.

When the record head is completely worn out, the gap begins to open up and the required peak bias current increases due to the greater ampere-turns needed to cause the bias flux to jump the wider gap. Thus, the worn out record head can be visually identified by an excessively-wide gap and electrically recognized by an unusually-high bias requirement. Recording quality will also be significantly degraded.

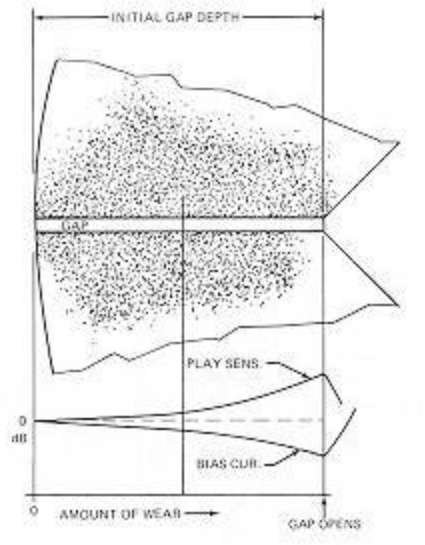


Figure 2. Sensitivity Vs. Wear

1.4 Wear Patterns

The magnetic recording tape eventually wears a groove into the face of the head, causing performance problems. Uneven and irregular wear patterns can physically distort the tape, curl its edges, cause excessive oxide buildup and result in separation of the tape from contact with the head face to produce associated losses in important high-frequency performance.

Figure 3 illustrates some typical wear patterns which create problems in both recording and reproduction. Figure 3A represents an ideal symmetrical wear condition not usually recognized in practice. Here, the groove has straight sides, square corners and a flat bottom that effectively serves as a tape guide. It will cause a minimum of problems unless the head height is accidentally shifted during adjustments, causing the tape to be dragged from its ideal, straight-line path. A reel of extra-wide tape can also result in edge curl and increased frictional drag since it will be slightly larger than the groove worn in normal use with regular-sized tape.

Figure 3B shows the sloped trapezoidal wear pattern caused by improper ZENITH adjustment of the head. If the face of the head is not perpendicular to the deck surface, the tape pressure will be greater on one edge, causing uneven wear. Figure 3C shows the convex wear pattern which can be caused by excessive tape tension while the concave pattern of Figure 3D with rounded groove corners occurs occasionally and may result from poor tape guidance or dissimilar head face materials at the tape edges.

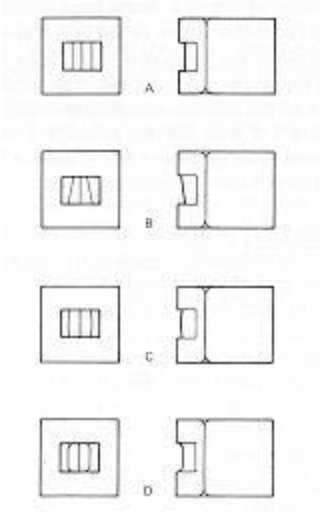


Figure 3. Head Wear Patterns

1.5 Edge Slots

Heads are often slotted at the edges of the tracks in order to alleviate some wear problems. Figure 4A illustrates the face of a full track with edge slots above and below the track. In the right view, looking at the side of the head, note that the tape is slightly wider than the track or pole and extends past tie track edges by 2 4 mils (0.05 - 0.10 mm) on both sides. The wear pattern is uniform and the edges of the tape do not contact the outer walls of the slots. Theoretically, in this ideal case, the head should never require relapping and may be used until it is completely worn out. In practice, however, the flattening of the tape contact area on the head nose reduces the effective per-unit tape pressure and can result in slight separation losses at the higher audio frequencies.

Figure 4B shows the effect of improper ZENITH adjustment and head height on a slotted head. The uneven wear pattern and narrow lip on one edge can result in response problems and damage to the tape.

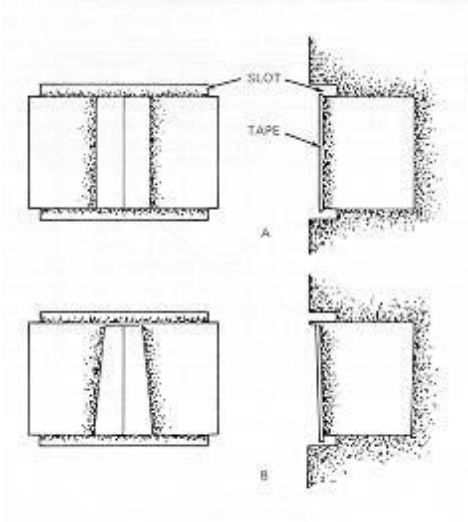


Figure 4. Edge Slots

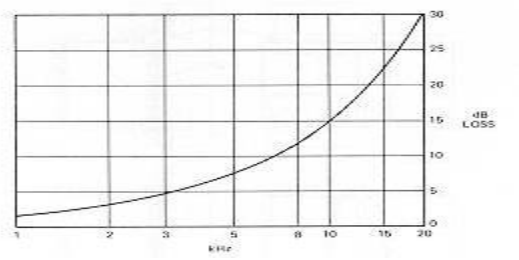
1.6 Spacing Losses

The degree of perfection of magnetic recording and playback is extremely dependent upon having the oxide surface of the tape pressed firmly in intimate contact to the head pole at the gap location. Any slight separation, even on the order of 10 micro-inches, will reduce recording and playback efficiency, particularly at higher audio frequencies. The physical separation can be caused by unevenly-worn heads, insufficient tape tension or a buildup of oxide deposits on the head face.

Figure 5 illustrates the dB loss vs. frequency caused by an air space between the tape and the face of the reproduce head.

The formula for the curve is

$$dB = 55\ d / \lambda \quad \text{where,}$$



.05-mil at 1.875 ips
(1.25µm at 4.75cm/sec.)

.10-mil at 3.75 ips
(2.5µm at 9.5cm/sec.)

.20-mil at 7.5 ips
(5.0µm at 19cm/sec.)

Figure 5. Spacing Loss

d is the spacing or separation and λ is the wavelength, both in mils or micrometers or other units. This formula reduces to dB = 15 dF, where d is the spacing in mils and F is the frequency in kHz, with a tape speed of 3.75 ips. The curve shown is correct for d = 0.1 mils at a speed of 3.75 ips. It can also be used for d = 0.05 mils at 1.875 ips and for d = 0.2 mils at 7.5 ips. It shows a fairly-severe loss of 15 dB at 10 kHz for a relatively-small separation, thus illustrating the importance of good contact between the tape and the head face.

1.7 Reducing Head Wear

The rate at which a head wears may be minimized by certain precautionary measures and adjustments. Wear is primarily a function of the following variables:

1. Tape speed.
2. Tape-to-head pressure.
3. The abrasive quality of the oxide surface.
4. The wear resistance of the head face.

Tape Speed directly affects head wear. However, at extremely-high speeds, such as those encountered in tape duplicators, tape tension may have to be increased to prevent "flying" of the tape caused by the air film being drawn between the head face and the tape itself.

Otherwise, we can normally expect the head wear rate to increase as tape speed goes up.

Pressure of the tape against the head face is very important in order to maintain intimate tape-to-gap contact. Low pressure will result in erratic or insufficient high-frequency response due to spacing losses. However, excessive pressure will cause accelerated head wear. To prevent this, the tape tension should be set at the factory specification for the given recorder. Lacking that information, the tension may be adjusted to the minimum value which provides adequate and consistent high-frequency response under the worse condition with a full tape supply reel producing minimum tension.

Pressure Pads if used, should be cleaned or else replaced if badly worn or mis-shapened. These pads are probably the worse offenders in causing abnormal head wear such as a dished-in cavity. The pad should be positioned directly over the head gap and should span the tape with an overlap on each edge. It should also apply pressure uniformly across the entire width of the tape. Pressures may run between 0.5 to 1 ounce (15-30 grams) but should be kept to the minimum that gives good performance at the higher frequencies. New pressure pads are supplied with NORTRONICS replacement heads.

Zenith Adjustment should be performed to position the head face so that it is perpendicular to the deck surface. This will ensure a uniform wear pattern as shown in Figure 3A, rather than the trapezoidal wear pattern illustrated in Figure 3B.

1.8 Head Relapping

Heads should be relapped whenever a wear pattern develops which might cause performance problems as described earlier. The exact time for relapping is difficult to determine. However, when in doubt, relapping should be performed, since a worn head will always perform better once relapped. In Figure 1, two suggested relapping points are indicated. The first is at about 5 mils (0.125 mm) wear depth and the second when an additional 5 mils of metal has worn away.

Figure 6 shows a typical full-track head with a wear groove. A cross-sectional view of the pole tips appears in Figure 6B with a flat spot worn by tape passage. In Figure 6C, the worn area has been relapped to produce a new radiused contour which is not quite as sharp as the original radius, but still rather adequate.

The NORTRONICS QM-707 HANDYLAP ™ Lapping Block is an excellent product for recontouring worn heads. It consists of a rugged plate glass block with a special vinyl/Mylar overlay to produce the very-best quality face polish. Two cam-actuated rubber rollers clamp the lapping film to the block, which is designed to operate under a water flow for cleanliness. Three different grades of abrasive sheets are furnished with the QM-707 Handylap and additional abrasive is available from Nortronics RecorderCare Dealers. The QM-707 includes a detailed set of instructions for the proper relapping of recording heads.

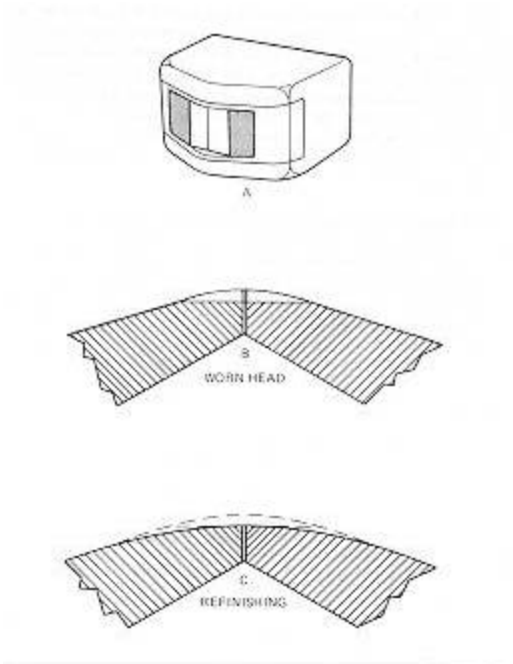


Figure 6. Head Contours

1.9 The Effect of Tape on Head Wear

The type of oxide and the smoothness of the oxide coating on the tape can greatly influence the life of a magnetic head. For example, it is well established that chromium dioxide tapes will wear away head materials almost twice as fast as

conventional iron oxides. This is a result of the shape and hardness of the oxide particles themselves. Also, virgin tape is more abrasive than tape that has been played a number of times because of the polishing and smoothing that takes place when the tape runs over the heads and tape guides.

Humidity-Ambient humidity is another important factor in head wear that is not too well known or understood. Tests indicate that head wear is relatively constant and independent of relative humidity up to about 50%. Above 50%, the wear increases to reach a figure of five to eight times normal at a humidity of 80%. High humidity will also aggravate oxide loading on head faces and increases the "sticktion" tendency of tape to seize or freeze to the head face at slow speeds or when cycled back and forth many times. The absorption of moisture by the oxide binder apparently may be the reason and most available tapes are susceptible to this problem while certain specialized tapes seem immune. The solution is to make certain that tapes are used and stored in areas where the relative humidity is maintained below 40%.

1.10 Long Wear Heads

The material used in the head face has a strong effect upon the rate of head wear and hard materials provide longer life. Some typical head core and face materials are described below:

1. **Hi-Mu 80**[1] also known as Mu-Metal and Permalloy is by far the most common magnetic core and shield material used for magnetic head construction. It has superb magnetic characteristics, is inexpensive and easy to process, is corrosion proof and accepts a high polish. In its annealed, high-permeability state, it is moderately soft and similar to brass in its wear characteristics. Life of a Hi-Mu head is adequate for a great many applications, typically 1,000 to 5,000 hours depending upon tape speed and other variables.
2. **Ferrite Heads** are manufactured using an extremely hard magnetic material made of magnetic oxide particles which are pressed together and fired in a furnace. The magnetic permeability and saturation flux capability of ferrite is inferior to that of Hi-Mu, although the high-frequency efficiency is better. Ferrite is most commonly used on erase heads, which are relatively non-critical as to surface and gap quality. Because it is made of small particles glued together, the ferrite material tends to suffer surface and gap deterioration with tape wear, caused by particle pull-out and gap erosion. Therefore, Hi-Mu is more widely used for recording and reproduce heads. These problems can be eased, but not entirely eliminated by using a costly "hot pressed" ferrite fired under high pressure. However, the final result is a very costly head suitable mainly for specialized applications such as high-speed duplication where the high-frequency efficiency and wear life are of prime concern. These features can be obtained more reliably and at less cost with the LTC ™ process described below.
3. **DURACORE**™ is a long-wearing, Hi-Mu material developed by Nortronics to improve head life using standard manufacturing procedures. Magnetic characteristics of the Duracore material are almost identical to those of standard Hi-Mu but wear life is increased by 5 to 10 times. At present, Nortronics is supplying Duracore to OEM customers on specific head models but is expected to find more general use in the future.[2]
4. **LTC**™ (Lifetime Ceramic) is, in our opinion, the ultimate process for increasing magnetic head life. Nortronics spent more than three years to develop the technique for applying a special ceramic material to the face of heads featuring standard Hi-Mu cores. The result is ahead with unsurpassed magnetic properties of Hi-Mu and the long-wear (over 50 X that of Hi-Mu) of Ferrite heads without their problems. The LTC head will truly last for the useable life of the recorder.
5. **Chrome**. Head life may be increased approximately 10 times by plating the face with a layer of hard chromium in a technique similar to that used with LTC, This process requires very careful masking of the head prior to immersion in the liquid plating solution, which is quite corrosive. Cost is comparable to that of LTC but the wear life is inferior.

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1 Trademark of Carpenter Technology, Reading, PA.

2 See also: New Wear-Resistant Permalloy Material for Magnetic Recording-Head Application, Steven A. Bendson, Nortronics Company, Inc., Journal of the Audio Engineering Society, September 1976.

™ Nortronics Company, Inc.

2. QM-707 HANDYLAP™ - INSTRUCTIONS

2.1 Kit Contents

The QM-707 HANDYLAP kit consists of a lapping block and accessories capable of completely relapping a worn magnetic tape head. The following parts are included with the QM-707:

PARTS LIST

D-1078	Lapping Block.
QM-702	Coarse Abrasive (black). Five sheets 5" by 9". #400 3M WETORDRY TRI-M-MITE, Silicon Carbide.
QM-703	Medium Abrasive (yellow). Five sheets 5" x 9", 12-micron Aluminum Oxide. 3M Imperial Lapping Film, 2-mil polyester backing.
QM-704	Fine Abrasive (red). Five sheets 5" x 9", 3-micron Aluminum Oxide. 3M Imperial Lapping Film, 2-mil back.
D-1090	Magnifying Inspection Lens.
D-1092	Head Support Angle.
D-1093	Head Holder.

2.2 Description

The D-1078 Lapping Block is ruggedly constructed of high quality components to provide years of reliable service. It consists of a 3/8-inch thick plate class block 5-1/2 inches wide by 7-1/2 inches long, covered with a special 8-mil vinyl film having a 1-mil Mylar overlay. This plastic coating protects the glass block from nicks and scratches, and also provides a slightly resilient backing for the abrasive film to improve the lapping characteristics. It gives a better final polish and reduces the tendency for the lapping film to become torn or scratched during the lapping process.

On each end of the glass block is a rubber-covered spring-loaded eccentric cam-roller which draws and clamps the abrasive film tightly to the surface of the block. Two heavy Cycolac plastic side rails support the block and the two rollers.

Accessories include the D-1090 Magnifying Lens for inspecting the heads, D-1092 Support Angle for keeping the head vertical during lapping, and D-1093 Head Holder to aid in grasping the head. An initial supply of the three grades of abrasive sheets is furnished, and additional quantities may be obtained from your Nortronics Dealer.

2.3 Lapping Procedure

The following detailed head relapping instructions should make it possible for even a novice to adequately recontour and polish a worn head to achieve "like new" performance. "First time" head relappers are urged to develop skill by practicing on worn-out heads before attempting to relap a slightly worn head.

2.3.1 Worn Out Heads.

Other than for practice, there is no point in relapping a worn out head as its performance will continue to deteriorate very rapidly. Study the previous section on Head Wear Factors. It will help in making the determination as to whether a particular head is relappable or is completely worn out, as evidenced by breakdown and opening of the gap, illustrated by the drawing of Figure 7.

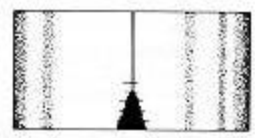

Figure 7

Use of the Magnifying Lens will aid the operator to visually detect this gap line evidence indicating a fully worn out head. Even a slight opening or sign of metal deterioration in the gap area, will signal the absolute end of the head's useful life.

2.3.2 Cleanliness.

It is extremely important to maintain antiseptic freedom from dirt and grit on the abrasive surface and between the lapping film and the block, particularly when using the medium and fine grades of abrasive. Otherwise scratches can develop on the head face.

2.3.3 Water

Running water flowing across the surface of the abrasive on the block is recommended. It will improve cutting action by flushing away metal particles and also remove loose grit grains which can scratch the head. The lapping block may be placed in a sink, preferably on a raised platform, with water from the tap continuously falling on the surface.

If running water is not available or convenient, the block may be mounted inside a shallow cake pan, using a pair of building bricks as a platform tilted at a slight angle with a wooden block as shown in Figure 8.

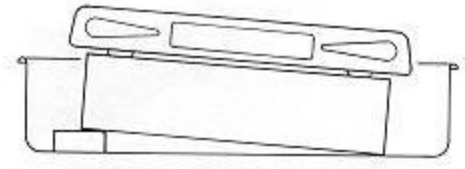

Figure 8

Water from a pitcher or similar container should be poured over the abrasive surface at frequent intervals during the lapping procedure. Add a half-teaspoon of liquid detergent to a quart of water to reduce surface tension, increase wetting action and aid in cleaning. The weight of the bricks is adequate to hold them in place as the pan fills with water.

Another method for using water, is to immerse the block in a pan so the water level is maintained from 1/8-inch to 1/4-inch above the lapping surface. Again, add the liquid detergent to the water for improved results.

NOTE Do not use kerosene or other mineral spirits, or solvents which can attack the rubber rollers and adhesives.

2.3.4 Loading the Abrasive Sheet

Figure 9

1. **Turn the roller levers** so their pointed ends face outward, away from the block as in Figure 9, separating the roller from the end of the block to allow insertion of the abrasive sheet.
2. **Turn the roller levers** so their pointed ends face outward, away from the block as in Figure 9, separating the roller from the end of the block to allow insertion of the abrasive sheet.
3. **Turn the roller levers** so their pointed ends face outward, away from the block as in Figure 9, separating the roller from the end of the block to allow insertion of the abrasive sheet.
4. **Wash with running water**, or wipe the block surface and the front and back sides of the abrasive sheet with a damp cloth to remove the static charge, dust and loose grit.

5. **Insert one end** of the abrasive sheet, about 1/2-inch, into the gap between the left roller and the end of the block, as shown in Figure 10. Rotate the left roller lever clockwise until the roller lightly clamps the film.

6. **Fold downward** about 1/2-inch of the free end of the sheet and insert the end into the other roller gap as shown in Figure 10 and Figure 11. With both rollers loosened, place one hand on the sheet and slide it about until it is centered on the block, then depress both lever ends simultaneously as shown in Figure 12, until the lever tips are resting on their pin stops. The lapping film should now be smooth and tight.

Figure 10

2.3.5 Coarse Lapping

The OM-702 black #400 abrasive material is used initially to rapidly remove the face material from the head and to eliminate the wear groove and recontour the face. It leaves fine scratches which are subsequently polished off with the Medium and Fine lapping films.

1. **Clamp the black** abrasive sheet and provide water for lapping as described in Section 2.3.4.

2. **Load the head** into the D-1093 Head Holder, if the head is of the Nortronics B-size. For light touchup work, the Head Holder may not be necessary, as is the case for larger size heads. Do not tighten the set screw of the D-1093 excessively as it can ruin a head by distorting the case and cores.

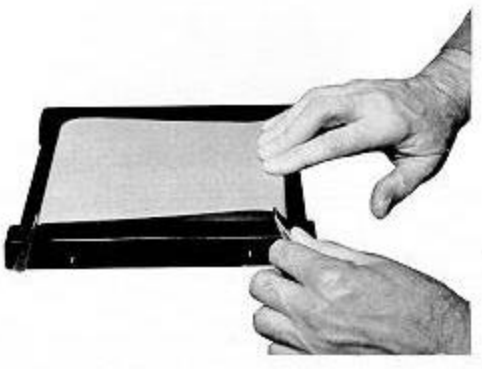

Figure 11

3. **Grasp the head** between thumb and forefinger as shown in Figure 13 (with Head Holder) and in Figure 14 (with no Head Holder). A comfortable orientation position for the lapping block is at 45 degrees to the operator, as for a sheet of writing paper. The two lever handles would be located along the top edge of the paper sheet.

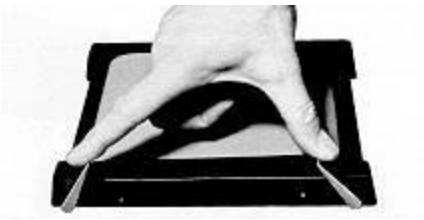

Figure 12

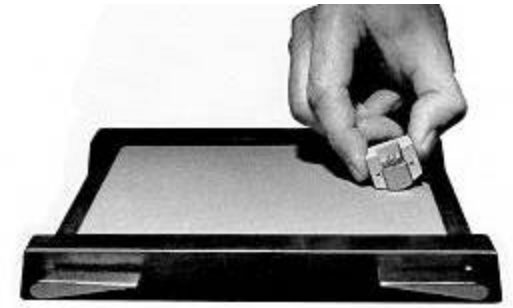

Figure 13

Figure 14

4. **Move the head** back and forth, from left to right and from right to left while rocking the head in the direction which increases the speed of face travel over the abrasive. Refer to Figure 15 and to Figure 16 for a pictorial representation of this critical rocking and stroking action. The face of the head should be kept squarely on the abrasive surface, and a uniform constant pressure maintained, otherwise the nose of the head can deviate from its ideal cylindrical curvature, becoming somewhat spherical.

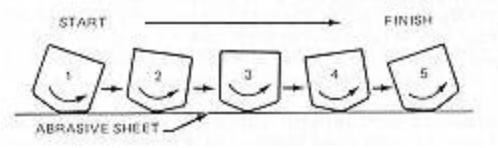

Figure 15

Figure 17

Figure 17 shows a pair of full-track Record/Play heads; the head on the left has been relapped, while the one on the right is a worn head with the flattened area evident at the center of the face. In Figure 18, "A" is the worn head with "B" showing a cross-sectional view of the pole pieces and the worn area or flattened bottom of the wear groove. In "C" the nose of the head has been recontoured to round off the flat spot and remove the high ridges, producing a smoothly radiused shape similar to the original. The radius of curvature has been increased somewhat, but not enough to cause a problem.

Figure 16

4. **Continue to lap** against the coarse abrasive, moving the head to a new location as the cutting action decreases. Use the Magnifying Lens to inspect the head face for shiny spots, remains of the original worn flat spot, and to make certain that the nose of the head is being contoured into a smooth curve with the gap located on the crest of the curvature. When no more shiny spots remain, the head is ready for lapping against the Medium lapping film.

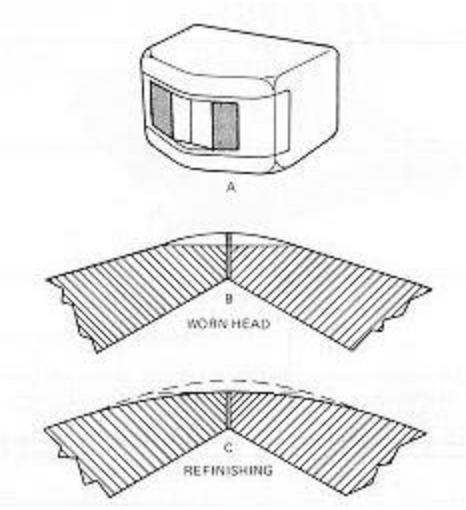

Figure 18

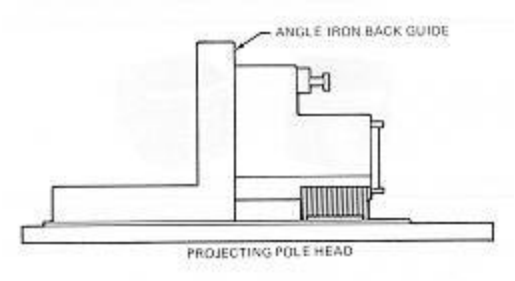

Figure 19

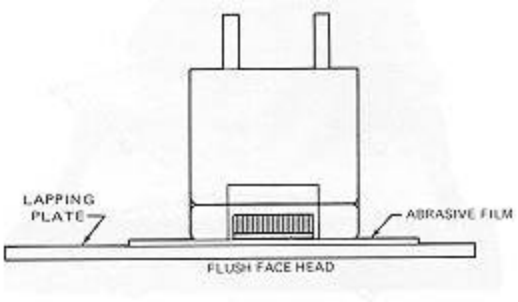

Figure 20

5. **The Head Support Angle** is needed to support a projecting pole head as illustrated in Figure 19 compared to a flush face head shown in lapping position in Figure 20.

The flush face head normally has enough face contact area to keep the head vertical during the coarse lapping as shown in Figure 20, where the face material on either side of the wear-groove gives stability. However, there is no harm, and there are advantages, in using the backup Support Angle even for flush face heads to prevent accidental rounding of the face during coarse lapping.

The AMPEX-style full track head shown in Figure 18 needs the Support Angle, as do other heads with projecting poles such as those used on hard surfaces like credit cards, motion picture film, ledger cards, etc. In Figure 21, the Support Angle is placed on the lapping block surface, metal surface down and plastic face vertical. The Angle is held in place with one hand while the head is pressed against the vertical surface with the other hand. Move and rock the head in the same manner as described previously in Step 4., while maintaining pressure between the base of the head or the Head Holder and the low-friction plastic vertical surface of the Support Angle. Move the Angle from time to time to allow the head to contact fresh abrasive.

Figure 21

2.3.6 Medium and Fine Lapping

1. **Remove the coarse** abrasive sheet and carefully wash and flush the lapping block to remove all particles of the coarse grit,
2. **Reload with the yellow** Medium Lapping Film after first rinsing the sheet with water as described in Section 2.3.4.
3. **Flush the head** with water to remove any grit particles which may be clinging to it. Then proceed with the lapping procedure as described in Section 2.3.5. in order to remove the scratches left on the head face by the coarse abrasive. Inspect the head face with the Magnifier to verify that the heavy scratches and all flat spots are removed.
4. **Repeat the above procedure** for **Fine** lapping with the fine red lapping film. This will put the final finishing polish on the head face. If all steps were carefully and faithfully followed, the resultant relapped head should be equivalent in performance to the original head when new.

2.3.7 Worn Out Heads

With the Magnifier, carefully inspect the head gap. It is entirely possible for the relapped head to have developed an open gap because it is completely worn out from the tape and from the relapping process. This will be obvious with the aid of the magnifying glass as a breakdown of the thin, feathering metal immediately adjacent to the gap, and the widening black gap line. If the head shows these symptoms of excessive wear, it must be discarded and replaced with a new head.

Figure 22

2.4 Bare Bones Lapping Kit

Since the QM-707 Handylap lapping block is no longer made, you will have to improvise if you don't already own one. Figure 23 and the following list of materials is all you need to turn your kitchen sink into a precision head lapping tool.

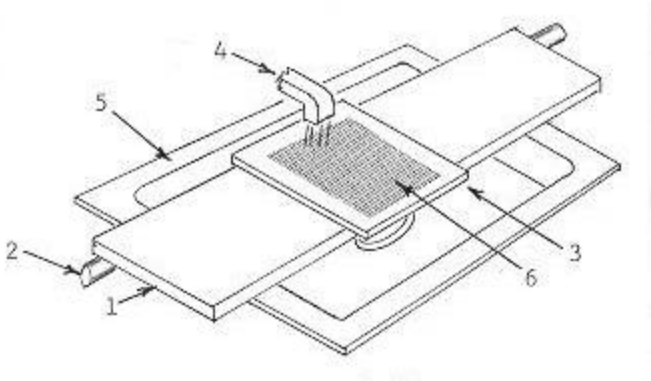

Figure 23
Bare Bones Lapping Kit
(For those without Handylap)

PARTS LIST

1.	PINE BOARD, "One by ten"(3/4" x 9-1/4"), 26-in.long.
2.	WOOD DOWEL, 3/4" dia. x 28", nailed to edge of board.
3.	PLATE GLASS, 3/8' or 1/4" thick, size 6" x 10", optically flat if possible. Cement it to center of board using hotmelt glue or epoxy.
4.	RUNNING WATER, cold or cool. ***NOTE***: The wet glass plate will hold the abrasive sheets in place.
5.	LAUNDRY TUB or kitchen sink.
6.	ABRASIVE SHEETS size approximately 5" x 9". Source: Go to "Abrasives" in Yellow Pages, the dealer who stocks 3M Abrasives. The exact grit sizes given are not sacred, just use the closest size available. The important thing is to progress in steps down from coarse to fine. You cannot easily remove deep scratches from the coarse paper with the fine polishing film
	a. 3M TRIMITE WET OR DRY silicon carbide. 400-grit to remove all steps and flat spots. 1500-grit to remove the 400-grit scratches.
	b. 3M IMPERIAL LAPPING FILM. 9-micron (blue) 3-micron (pink) 1-micron (lavender)
:	NOTE: 12-micron yellow is OK in place of the 9µ. If you can't find 3µ, you'll just have to work harder with the 1µ. 0.5µ is OK substitute for 1µ. A good magnifying glass or binocular microscope is needed for inspection to make certain no flaws remain.

NORTRONICS

Nortronics Company
Minneapolis Minnesota

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As of some time prior to this reissue the Nortronics Company has ceased to exist. It has been sold several times and its audio heads are no longer being manufactured.

However, Joe Dundovic, the author of this manual, has a large stock of Nortronics heads available for immediate delivery. He may be reached via his Magnetic Head Stock Room web site: http://magneticheadstockroom.com/