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Technical Supplement The Nakamichi „SuperHead"

All Nakamichi cassette decks have at their heart the Crystal Permalloy head, an advanced magnetic device developed by Nakamichi Research. The Crystal Permalloy head is produced in two versions: a 1 micron gap unit for playback only (used in both Nakamichi three-head cassette decks), and a 1.5 micron gap „Focused-Field" unit for record/playback purposes (used in all Nakamichi two-head decks). These heads are largely responsible for the excellent frequency and dynamic range performance of Nakamichi decks.

Although the Crystal Permalloy head is already close to the ideal magnetic head in terms of its electrical performance, Nakamichi has succeeded in further refining the manufacturing process, yielding a new Crystal Permalloy „SuperHead". The Nakamichi „SuperHead" retains all of the magnetic characteristics of the original Crystal Permalloy head, but offers the advantage of incredibly long life when used in Nakamichi cassette decks.

In recent years, the market has been bombarded by a number of new head designs, each claiming significant advances in electrical performance and longevity. Ferrite was the breakthrough in magnetic heads a few years ago, but many manufacturers, who were quick to jump on the ferrite bandwagon, now seem to be back to the use of mu-metal and hard permalloy heads. More recently, the sendust alloy head seems to be making a bid for state-of-the-art honors. Manufacturers planning to use sendust heads claim that the alloy is as hard as ferrite (and is therefore equally resistant to wear) but offers the superior magnetic characteristics of permalloy.

Nakamichi has always felt that head longevity is important, but only if it can be attained without sacrificing actual performance. A study of the magnetic characteristics of the various head core materials in use today show that those heads claiming long life by virtue of their hardness, including sendust alloy heads, are actually inferior in performance to even conventional hard permalloy heads, particularly in narrow gap applications.

A playback head, whether it is a playback-only head in a three-head design or a combination rec/pb head in a two-head configuration, is designed with a narrow gap since it must deal with weak flux levels, namely signals previously imprinted onto the tape. Because of the low flux levels involved, the initial magnetization characteristics of the core material become extremely important. All magnetic materials exhibit some non-linearity at initial magnetization. The amount of non-linearity determines the suitability of a particular material for use as a playback head. Materials exhibiting greater initial linearity will provide lower distortion in the narrow gap application.

Figure 1 is a plot of the magnetization characteristics of four materials: conventional hard permalloy, ferrite, sendust alloy, and Nakamichi Crystal Permalloy. The dotted lines indicate the paths of initial magnetization, while the solid lines trace the various hysteresis loop characteristics. The horizontal axis is Coercive Force (H_c) in Oersteds. Materials with high

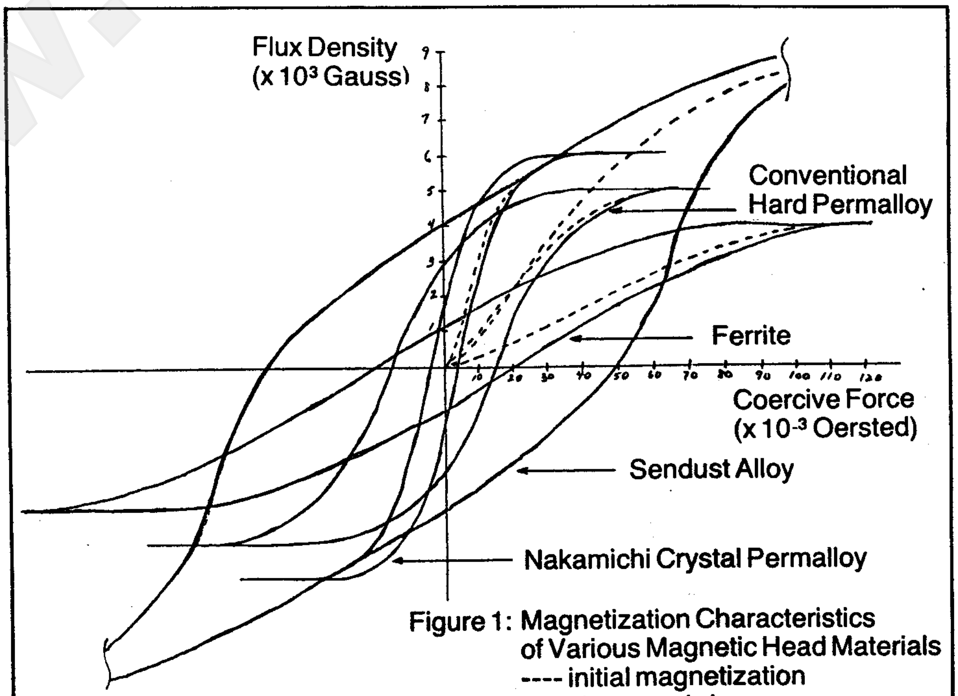

Figure 1: Magnetization Characteristics of Various Magnetic Head Materials
---- initial magnetization
——hysteresis loop

coercivity display rather elongated hysteresis loops and highly non-linear initial magnetization. Nakamichi Crystal Permalloy is characterized by a highly desirable low coercivity. Its hysteresis loop is very vertical; its initial magnetization, as a result, is comparatively linear.

The new Crystal Permalloy ,,SuperHead" made its first appearance on the market in 1977 as the playback head in the Nakamichi 1000 II and 700 II three-head cassette decks. More recently, Nakamichi has succeeded in producing a 1.5 micron gap version for use in its two-head machines. The Focused Field ,,SuperHead" shares the linear playback characteristics of the 1 micron ,,SuperHead", but, thanks to a slightly wider gap and Nakamichi's proprietary low stress manufacturing process, it is also capable of recording with performance levels unmatched by even some wide gap record-only designs.

During the recording process, the strength of the magnetic field generated by the head is controlled by the amount of bias current supplied to it. The strength of the field must be matched to the tape's coercivity so that an appropriate ,,critical zone" is generated. Figure 2 illustrates the magnetic field and critical zones generated by wide gap (a) and narrow gap (b) designs. The critical zone can be thought of as the ,,effective" gap of a record head. For proper recording, the radius of the critical zone must be such that the full depth of the tape coating is utilized. The implication of figure 2 is that a well designed narrow gap head should be capable of meeting this requirement as well as a wide gap device.

The difficulty in designing a narrow gap head with proper recording characteristics arises from the fact that the flux density at the core is much higher in a narrow gap design. A narrow gap core is

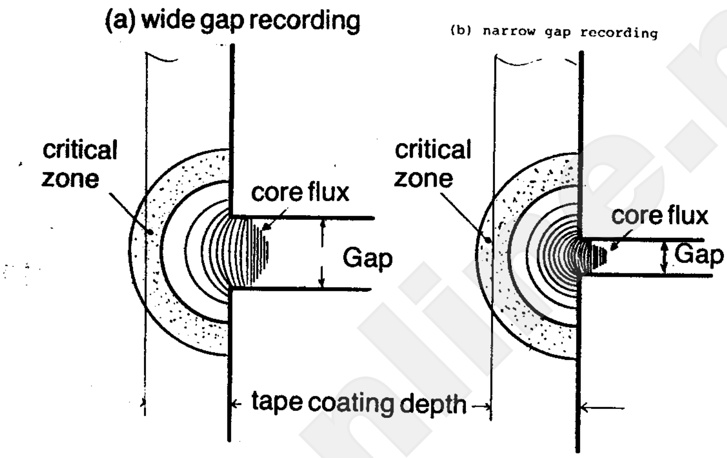

Figure 2: Wide vs. Narrow Gap Recording

thus prone to early saturation. When the core saturates, effective permeability drops dramatically; this has the effect of ,,flattening" the critical zone. Increasing bias current to the head at this point only drives the core into further saturation. Since the critical zone, and therefore the effective gap, is widened, the recording of high frequencies suffers tremendously. A wide gap record head is happily free of these problems, but a wide gap head would not do in a two-head design because it must also function as a playback head.

Since the narrow gap combination head is operated at or near its saturation point during record, the slightest stress on the core material during manufacture can have disastrous effects. Minute distortions of the alloy's molecular structure caused by manufacturing stresses will result in early core saturation. It is no surprise, then, that most two-head cassette decks are forced to settle for compromised high frequency performance. Attempts to regain full bandwidth with electronic compensation can only result in degradation of other performance parameters, such as signal-to-noise ratio. The Nakamichi Crystal Permalloy ,,SuperHead" is able to provide a focused critical zone without early core saturation because of a unique manufacturing process which goes to great lengths to avoid stress. The succes of the design is evident in Nakamichi two-head decks, all of which provide extended high frequency and dynamic range performance. The ,,SuperHead" also provides extremely stable performance, thanks to a ,,living" construction which makes the head capable of automatic internal temperature compensation.

As mentioned earlier, the Nakamichi ,,SuperHead" is an extremely long-life head. Nakamichi has attacked the problem of head life, however, in a manner quite unlike any other. It is true that harder head material will wear less and, therefore, provide longer life. But Figure 1 and Table 1 clearly show that the hardest materials known (ferrite and sendust alloy) have serious drawbacks, namely high coercivity. Crystal Permalloy is not as hard as ferrite or sendust alloy, and yet the life expectancy of the Nakamichi ,,SuperHead" is conservatively quoted as 10,000 hours, an unprecedented figure. The ,,secret" lies in a new process whereby two horizontal cutouts are made in the surface of the head: one immediately below the bottom (left channel) core lamination, and another higher above. The remaining surface width between the two cutouts is precisely the width of the tape (see photos). Figure 3 provides a comparison of a conventional head (a) to the Nakamichi ,,SuperHead" (b). The wear pattern on the conventional head is extremely uneven because of variation in tape widths and unsteady tape travel across the head. Even with the aid of a pressure pad, the tape is unable to make perfect contact with the core; the result is severe degradation of sound quality. The deep gap design of the Nakamichi ,,SuperHead", on the other hand, combined with the head surface cutouts, permit extremely even wear with no loss of tape-to-core contact.

The simplicity of the solution will undoubtedly prompt observers to comment, ,,Why didn't somebody think of this before?". The fact is that it is no easy matter to execute precise cutouts on the surface of a head. The bottom cutout lies immediately beneath the edge of the left channel core. There is no physical structure supporting the bottom-most laminations. The real ,,secret", therefore, lies in the design of a laminated core that is structurally sound without perimeter support. It is also extremely important that the cutouts be made without physical stress on the core or head surface material. This requirement precludes the use of any

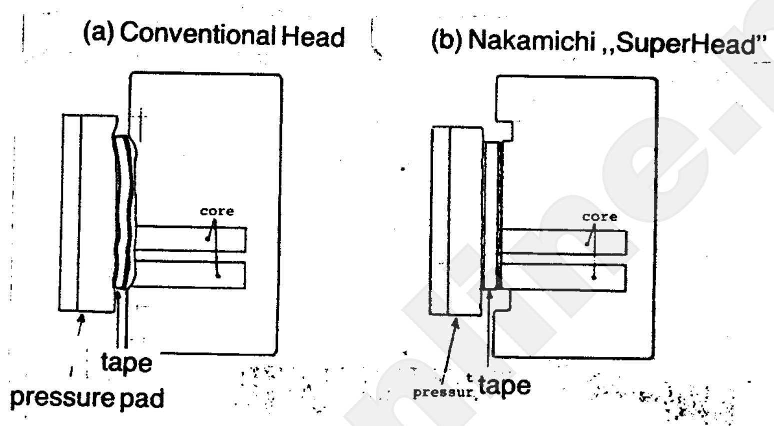

Figure 3: Headwear Characteristics of Conventional Head vs. Nakamichi ,,SuperHead"

Material	Composition (%)	Initial Permeability μ_0	Maximum Permeability μ_m	Coercive Force H_c (Oe)	Maximum Flux Density B_r (G)	Specific Resistance (μΩ - cm)	Curie Point T_c (°C)	Specific Density	Hardness H.V.
Nakamichi Crystal Permalloy	79 Ni, Nb, Ta	120,000	300,000	0,004	6,000	80	250	8.75	200
Conventional Hard Permalloy	79 Ni, Mc, Nb Ti	88,000	100,000	0,015	5,000	100	300	8.75	200
Permalloy (Mu-metal)	78 Ni, Cr, Mo Cu	50,000	200,000	0,015	7,000	60	350	8.62	120
Alperm	16 Al, Fe	3,000	55,000	0,04	8,000	140	400	6.5	350
Sendust Alloy	5.5 Al, 9.5 Si, Fe	30,000	120,000	0,05	10,000	80	500	6.8	500
Ferrite	Mn, Zn, Oxyde	20,000	40,000	0,02	4,000	3×10^6	100	5.15	650

Table 1: Physical Properties of Various Head Core Materials

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conventional method using abrasion as the prime means of removing material!

The 10,000 hour life expectancy quoted for the Crystal Permalloy ,,SuperHead" is substantiated by head wear tests, the results of which are summarized in Figure 4. 1.5 micron gap ,,SuperHeads" were mounted in two Nakamichi 600 cassette decks. Nakamichi SX tape was used throughout. Every 100 hours, the cassettes were replaced with fresh, unused ones; also every 100 hours, all parts in contact with the tape (heads, capstans, pressure rollers, tape guides) were cleaned with alcohol. The actual measurements were performed with a single test tape which was used from beginning to end. The data clearly confirm stable performance for a minimum of 10,000 hours. After 10,000 hours of use, the two test heads exhibit a change in 20 kHz playback response of less than 2 dB, and a change in 18 kHz rec/pb response of less than 2.5 dB. The two Nakamichi 600 decks remained totally unaltered throughout the tests – no bias or equalization adjustment of any kind were made.

A useful head life of 10,000 hours means that a user who plays his deck an average of five hours per day need not replace heads for six years. Nakamichi has, in other words, perfected a truly long-life head with performance demonstrably superior to any other type of cassette deck head in existence today.

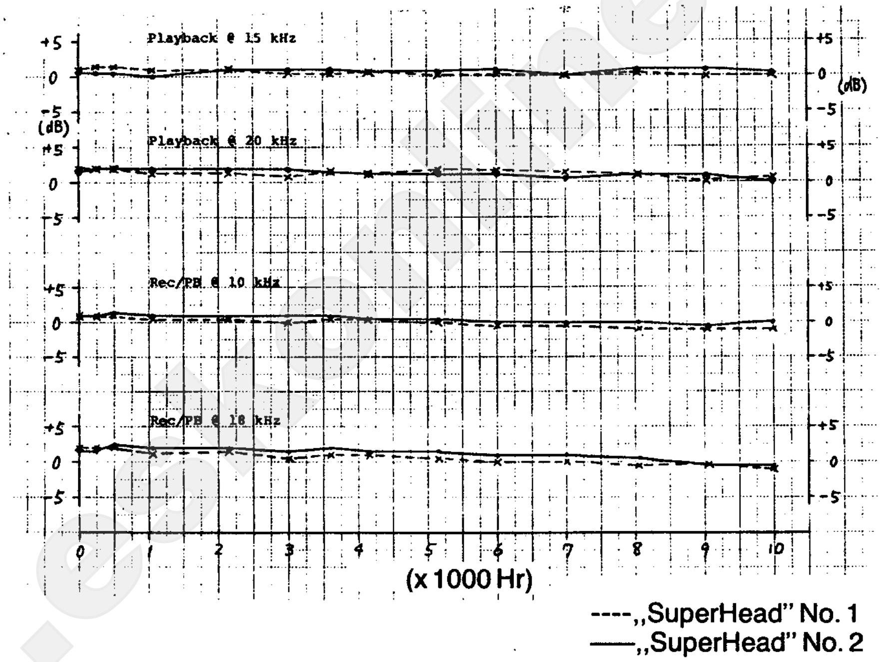

Figure 4: Results of Nakamichi ,,SuperHead" Life Test (see text)