OPTIMUM BIAS PARAMETERS FOR MAGNETIC RECORDERS

Presented by
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ABSTRACT

This paper provides a comparative analysis of popular professional recording tapes as regards optimum bias settings for minimum distortion. Hopefully this presentation will assist the professional recording community in a number of ways. First and formost, it should help educate the user in the more subtle aspects of tape biasing. Secondly, it should prompt tape manufacturers to examine areas where their product might be improved. Lastly, it might help us correlate technical measurements with subjective listening tests.

This presentation is a comparative study of the following topics:

1. Harmonic distortion versus bias level and recorded fluxivity hereby referred to as "Tape Signature".

2. Changes in Tape Signature when used with a significantly different bias frequency.

3. Low frequency distortion and its relationship to SMPTE IM Distortion measurements.
   IM Distortion and its relationship with Modulation Noise.

4. An alternate method in measuring Modulation Noise.

HISTORY

Presently the professional recording community biases their tapes based on a variety of different approaches; some are based on subjective listening tests, some on tape manufacturers recommendations. Others make their own assessment based on the old rule of thumb, that the more bias the less distortion. This is only partially true being restricted to IM distortion at higher fluxivites only. More on this later.

The more bias applied beyond peak, the more high frequency loss encountered. In general, the distortion versus high frequency loss trade off has caused nearly everyone to have an opinion as to the biasing of different tape formulations.

DISTORTION AND BIAS

Figures 1 through 19 show harmonic distortion versus bias level and recorded fluxivity. These tests were conducted with a 1kHz fundamental. Third harmonic percentages were measured with a Hewlett Packard HP3582A Spectrum Analyzer. Tests with 120kHz bias frequency were performed with an MCI JH-110B 2-Track Recorder. Additional tests with 210kHz bias frequency were conducted with an MCI JH-24 Multitrack. All tests utilized a record head gap of 300u inches.

TAPES TESTED:

3M	250	15, 30 IPS	120kHz	210kHz
	226	15, 30 IPS	120kHz	210kHz
	206	7½, 15, 30 IPS	120kHz	
AMPEX	456	15, 30 IPS	120kHz	210kHz
AGFA	468	15, 30 IPS	120kHz	210kHz

There appears to be two distinctly different tape formulation philosophies when it comes to professional recording tapes. The 3M250 and AGFA 468 require a significantly greater amount of bias to achieve the same overbias point than do the Ampex 456 and the new 3M226. The differences are apparent; for instance, the 3M250 at 15IPS appears to have greater distortion at overbias settings that provide comparable high frequency loss to the AMPEX 456 or 3M226. Whereas this might be a consideration at 15IPS, 30IPS operation with 3M250 is very good. The AMPEX 456 and 3M226 have distortion minimas at significantly different overbias settings dependent on fluxivity level. This causes some difficulty in choosing the best overbias setting.

For general purpose operation, the author's choice in this case was to pick an overbias that both preserved high frequency response and provided lowest distortion in the 700nWb/m area (about 9dB above 250nWb/m). A good deal of peak program material does reach this point on a regular basis. Some types of program material might be more advantagiously recorded at fluxivities that provide more high frequency loss and lower distortion with lower fluxivity. These charts allow a good deal of alternative interpretation based upon different recording applications.

Picking the optimum bias point for each of these tapes is still a trade-off between distortion and high frequency loss, but now the picture is clearer. There is a distortion minima for each fluxivity level. These distortion minima are not always at the same overbias point. A logical approach would be to select a bias level in a manner that the high frequencies would not be severely attenuated and the middle to upper fluxivities would be at their minimum distortion points.

(See Comparison Chart, Page 4)

COMPARISON CHART

TAPE	OVERBIAS	20kHz RESPONCE @ 250nWb/m	3RD HARMONIC @ 250nWb/m	TAPE SPEED BIAS FREQUENCY
456	1.5	-.3	.25	30 IPS
250	1	-.8	.03	120kHz Bias
226	1	+.5	.03	
468	1	+.8	.1	
206	.5	+.5	.75	(Figures 1 thru 5)
456	3	-.5	.3	15 IPS
250	2	-1.3	.2	120kHz Bias
226	2.5	0	.1	
468	3	-1	.2	
206	2	+.5	.45	(Figures 6 thru 10)
206	3	-3 *	.5	7½ IPS 120kHz Bias (Figure 11)
456	1.75	0	.1	30 IPS
250	2.5	-.5	.25	210kHz Bias
226	1.5	+.5	.07	
468	3	-.5	.3	(Figures 12 thru 15)
456	4.5	-.8	.07	15 IPS
250	3	-1.3	.25	210kHz Bias
226	4.5	-1.2	.04	
468	4	-2	.35	(Figures 16 thru 19)

* MEASURED AT 10dB Below 250nWb/m

When a significantly different bias frequency is used, the Tape Signature is appreciably changed. The reason for this at present is unknown. It may be related to bias wavelength with respect to record head gap width, or perhaps the depth of bias penetration into the oxide coating. This being an application oriented presentation, we won't concern ourselves with the physics involved.

DISTORTION AND FREQUENCY

At high frequencies, tape saturation appears as a compression of the waveform. The higher the frequency, the lower the fluxivity at which this compression occurs. The compression that occurs at 12dB above reference level of 250nWb/m with a 1kHz signal is roughly equivalent to the compression that occurs at 6dB above Reference with a 10kHz signal. This in turn is roughly equal to the amount of compression that a 20kHz signal experiences at Reference. Low frequency distortion is different. At low frequencies the tape requires more bias to remain linear at high fluxivities, quite unlike high frequencies which requires less bias to remain unattenuated.

Low frequency distortion appears as a waveform curiously similar to an unbiased waveform. Figure 20 is typical of the graphical representation often used to describe the transfer function encountered between the record amplifier and the resultant signal magnetization on the tape, available for reproduction. This is obvious simplification of the issue. The justification for this short cut must be left for more advanced study, as it involves complexities that would be distracting to this presentation. What appears to be happening is that the center coercivity related "Dead Zone" in the magnetic transfer function curve gets wider at low frequencies.

Figures 21 through 24 show low frequency coercivity related distortion as demonstrated by percent hormonic content as fluxivity is increased. We can see a distinct difference between the two formulation philosophies again reflected in the manner in which the harmonic structures develope with increasing fluxivity.

INTERMODULATION DISTORTION

SMPTE IM measurements at fluxivities high enough to border on saturation of the 60 Hertz component would only reflect the low frequency distortion characteristic. Figure 25 demonstrates a SMPTE IM waveform in which the low frequency signal has been driven into distortion. Any high frequency signal riding on the saturating low frequency waveform would be diminished as the composite low frequency, high frequency and bias envelope encroached upon the center transfer function "Dead Zone". Increasing bias to extend low end linearity would only attenuate the high end and increase midband distortion. Low frequency distortion should be avoided by maintaining prudent recording levels.

SMPTE IM distortion measurements are misleading when operating at high fluxivities due to low frequency distortion. Lower fluxivity IM measurements have other inherent problems. When using commercially available IM analyzers, the IM distortion runs the risk of being masked by modulation noise. A spectrum analysis of the detected output of a SMPTE IM analyzer will show a great deal of amplitude modulation products not related to the 60Hz signal. These amplitude modulation products easily overwhelm the harmonically related products of the 60Hz signal. A true IM distortion analysis can be done using a Fast Fourier spectrum analyzer that can perform a true time domain average. Signals not harmonically related to the 60Hz triggering waveform are averaged out of the analysis.

MODULATION NOISE

By using a similar technique to that described above, the detected output of a commercially available SMPTE IM distortion unit, operating with the low frequency generator off, can be processed by a Spectrum analyzer. The result is a separable measurement of the amplitude modulation products or modulation noise. A direct spectral analysis of the sidebands themselves would not allow for discrimination of flutter related components from modulation noise. Figure 26 shows the Spectral Analysis of the detected modulation noise for AGFA 468 3M250 and 226 an AMPEX 456.

In these tests, no significant variation was found when bias levels were changed within the normal biasing range of the tapes. The tests presently being used for modulation noise testing involve a DC recording current with bias. This does not seem to relate directly with modulation noise propagated with midband audio signals. One significant difference exists by using this technique. The first 30Hz or so of sidebands around the source signal are lost to low frequency head and electronic limitations in addition to, reproduce equalization standards. There is indeed room for a good deal more investigation into this subject. Modulation noise is directly related to the surface irregularities and lubricative properties of the tape in question.

CONCLUSION

The data presented here should provide a definitive basis for bias level selection for the tapes tested with bias frequencies of 120 and 210kHz. SMPTE IM distortion measurements should be discouraged unless special care is taken to avoid measuring modulation noise and coercivity related low frequency harmonic distortion.

New procedures for measuring modulation noise should be standardized. Causes and cures for modulation noise should be carefully investigated such that this phenomenal can be minimized.

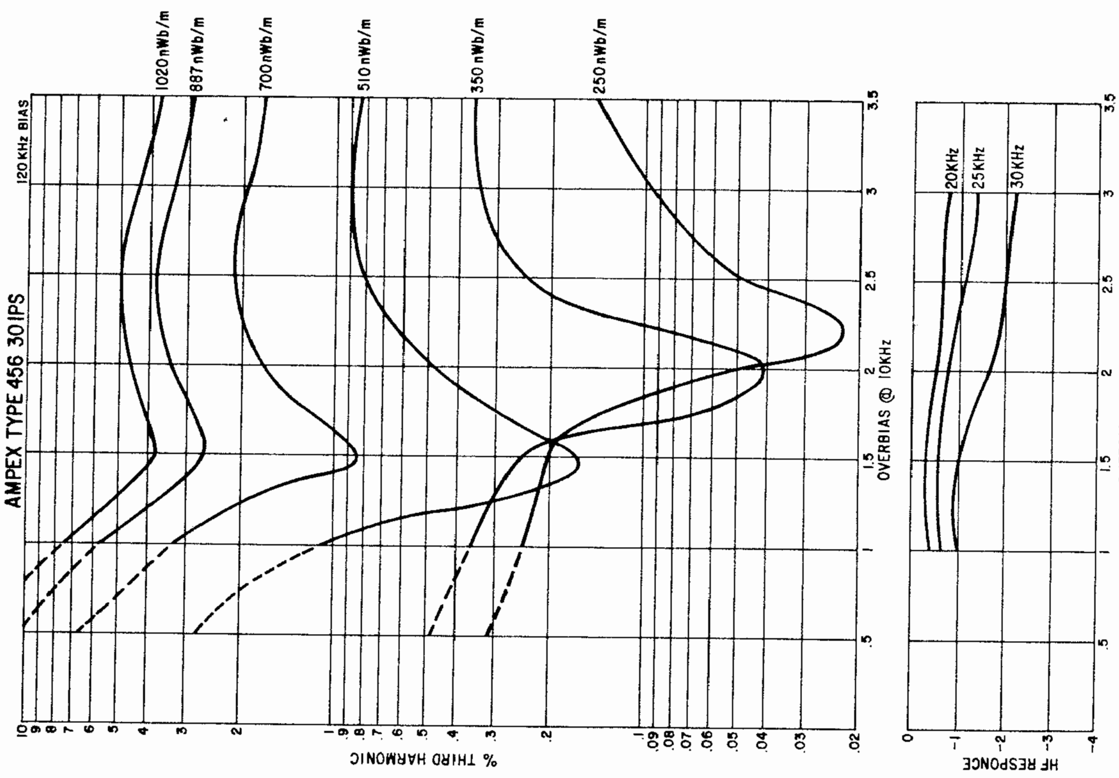

AMPEX TYPE 456 30 IPS
120 KHz BIAS
1020nWb/m
887nWb/m
700nWb/m
510nWb/m
350nWb/m
250nWb/m
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.03
.02
.5
1
1.5
2
2.5
3
3.5
OVERBIAS @ 10KHz
HF RESPONCE
0
-1
-2
-3
-4
20KHz
25KHz
30KHz

FIG. 1

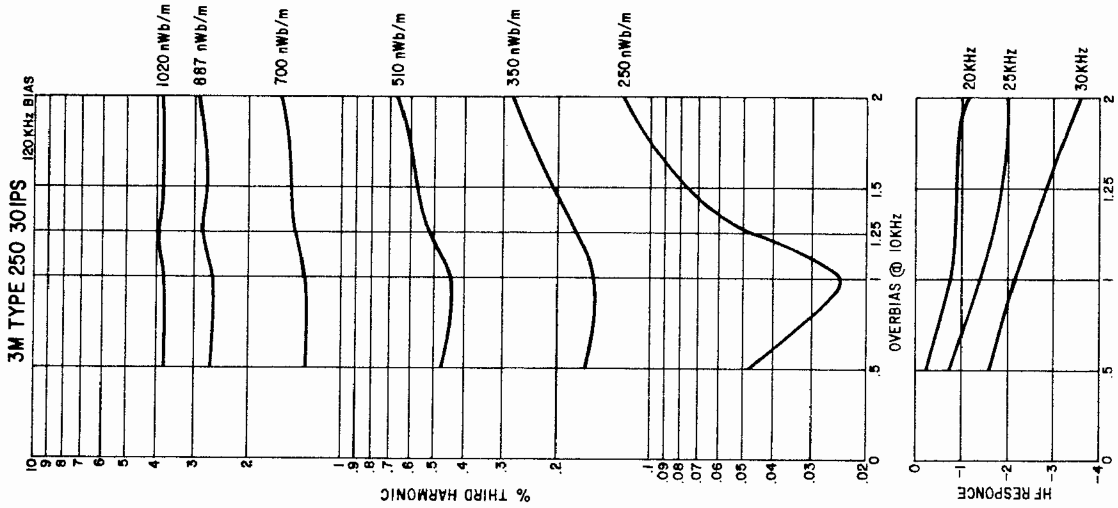

3M TYPE 250 30IPS
120 KHz BIAS
1020 nWb/m
887 nWb/m
700 nWb/m
510 nWb/m
350 nWb/m
250 nWb/m
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.03
.02
.5
1
1.25
1.5
2
OVERBIAS @ 10KHz
HF RESPONCE
0
-1
-2
-3
-4
20KHz
25KHz
30KHz

FIG. 2

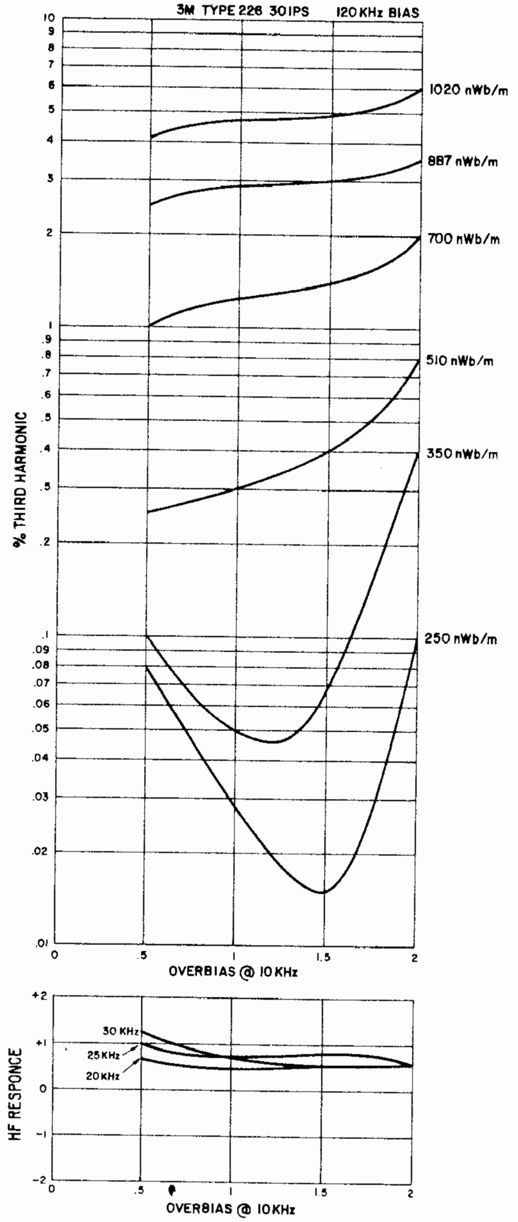


FIG. 3

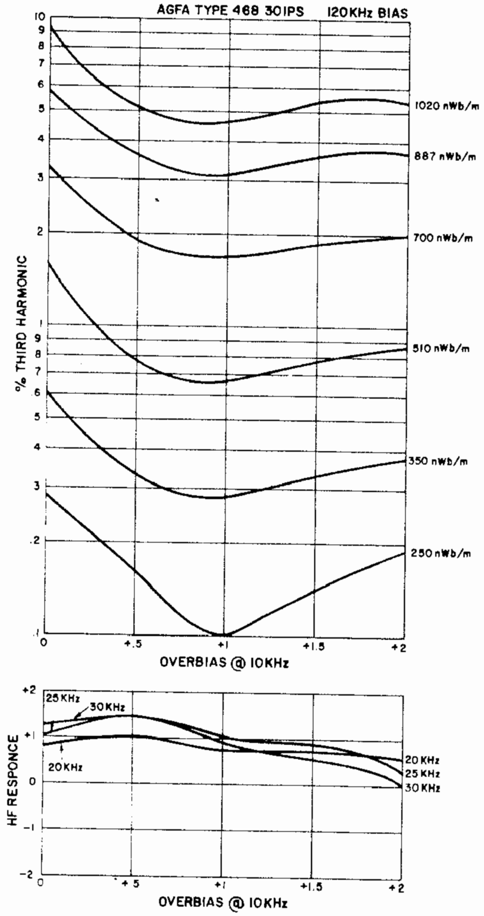


FIG. 4

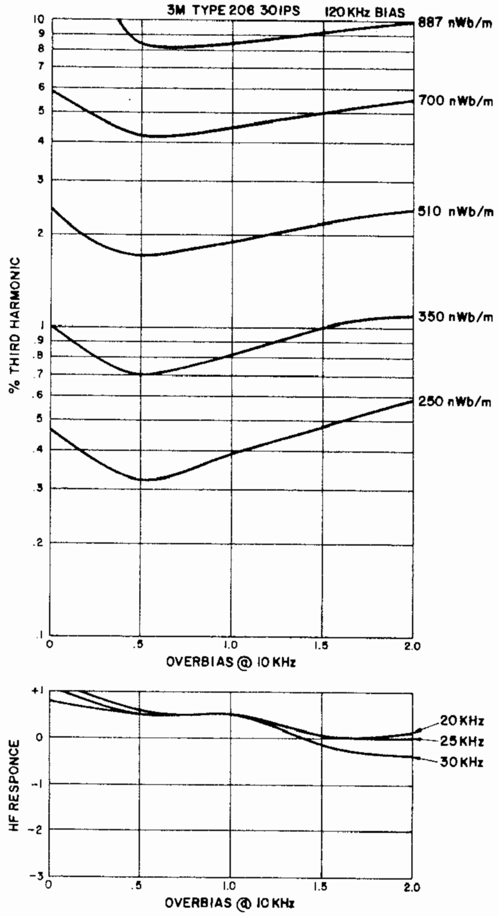


FIG. 5

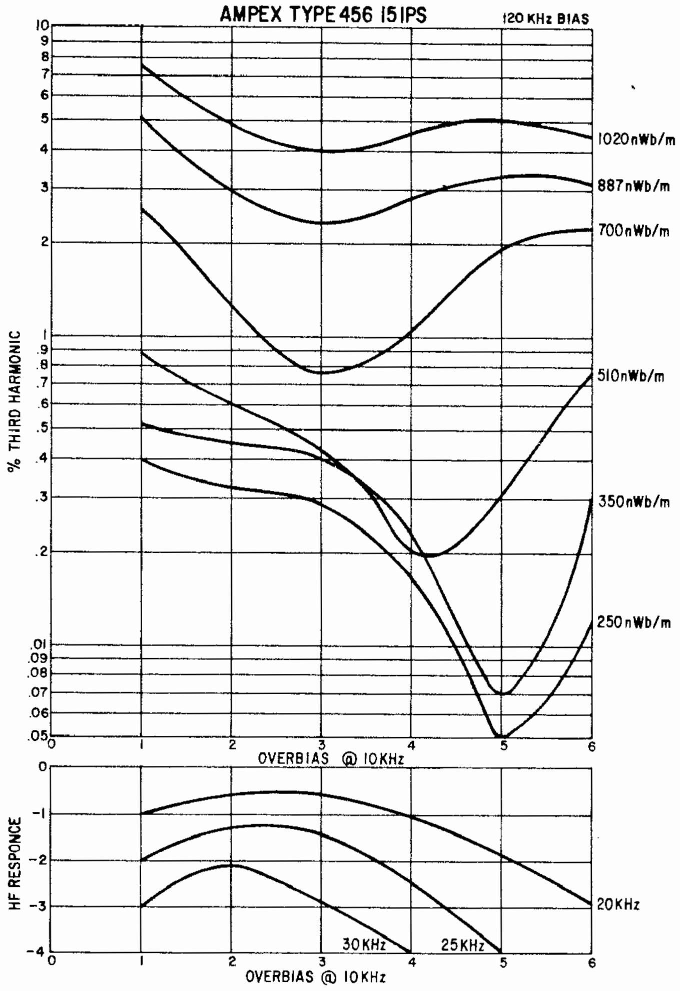

AMPEX TYPE 456 15 IPS
120 KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.01
.09
.08
.07
.06
.05
1020nWb/m
887nWb/m
700nWb/m
510nWb/m
350nWb/m
250nWb/m
0
1
2
3
4
5
6
OVERBIAS @ 10KHz
HF RESPONCE
0
-1
-2
-3
-4
20KHz
30KHz
25KHz
OVERBIAS @ 10KHz

FIG. 6

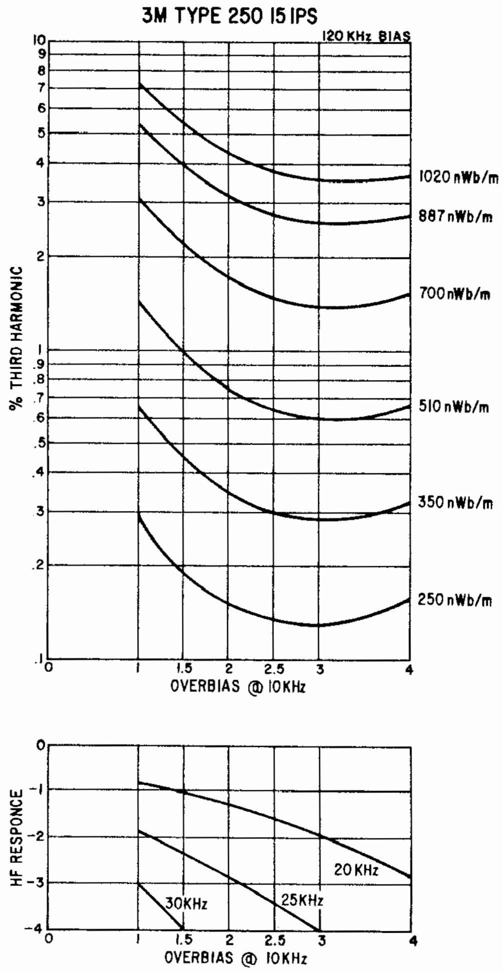

3M TYPE 250 15 IPS
120 KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
1020nWb/m
887nWb/m
700nWb/m
510nWb/m
350nWb/m
250nWb/m
0
1
1.5
2
2.5
3
4
OVERBIAS @ 10KHz
HF RESPONCE
0
-1
-2
-3
-4
20KHz
25KHz
30KHz
OVERBIAS @ 10KHz

FIG. 7

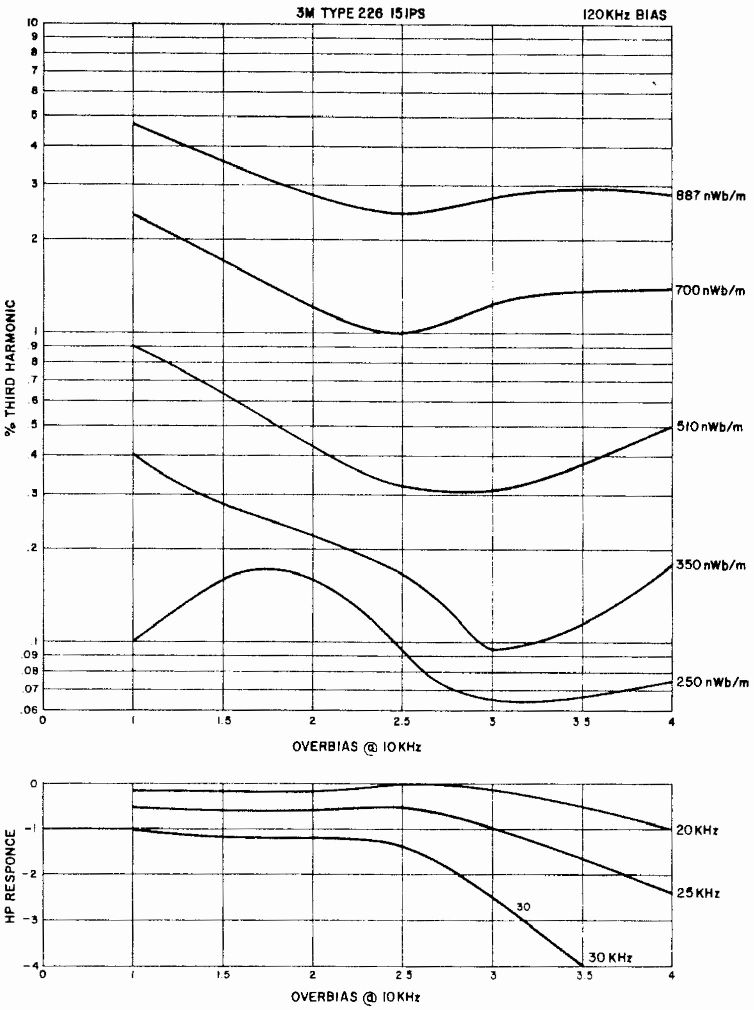

3M TYPE 226 15IPS
120KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
887 nWb/m
700 nWb/m
510 nWb/m
350 nWb/m
250 nWb/m
0
1
1.5
2
2.5
3
3.5
4
OVERBIAS @ 10KHz
HP RESPONCE
0
-1
-2
-3
-4
20KHz
25KHz
30
30 KHz
OVERBIAS @ 10KHz

FIG. 8

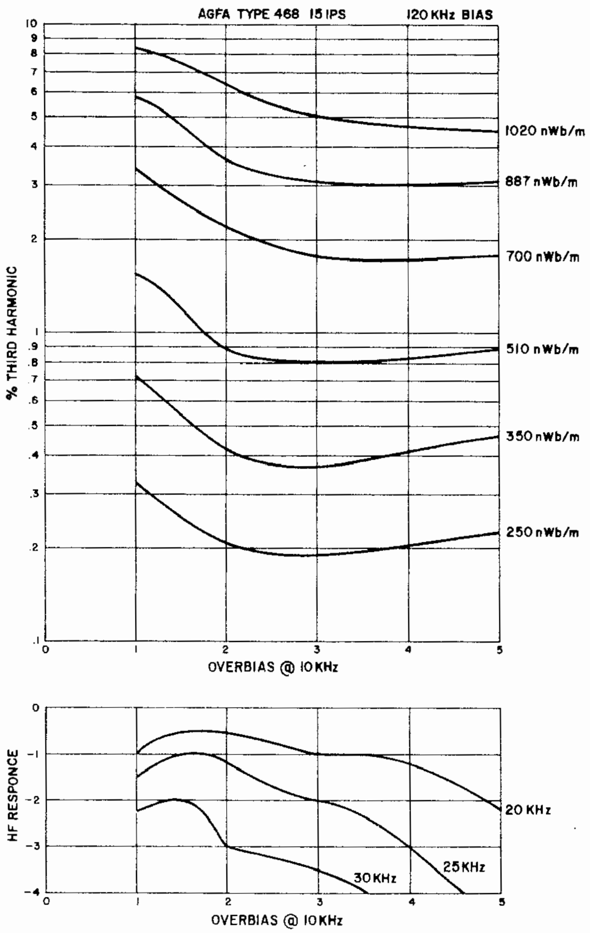

AGFA TYPE 468 15IPS
120KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
1020 nWb/m
887 nWb/m
700 nWb/m
510 nWb/m
350 nWb/m
250 nWb/m
0
1
2
3
4
5
OVERBIAS @ 10KHz
HF RESPONCE
0
-1
-2
-3
-4
20KHz
25KHz
30KHz
OVERBIAS @ 10KHz

FIG. 9

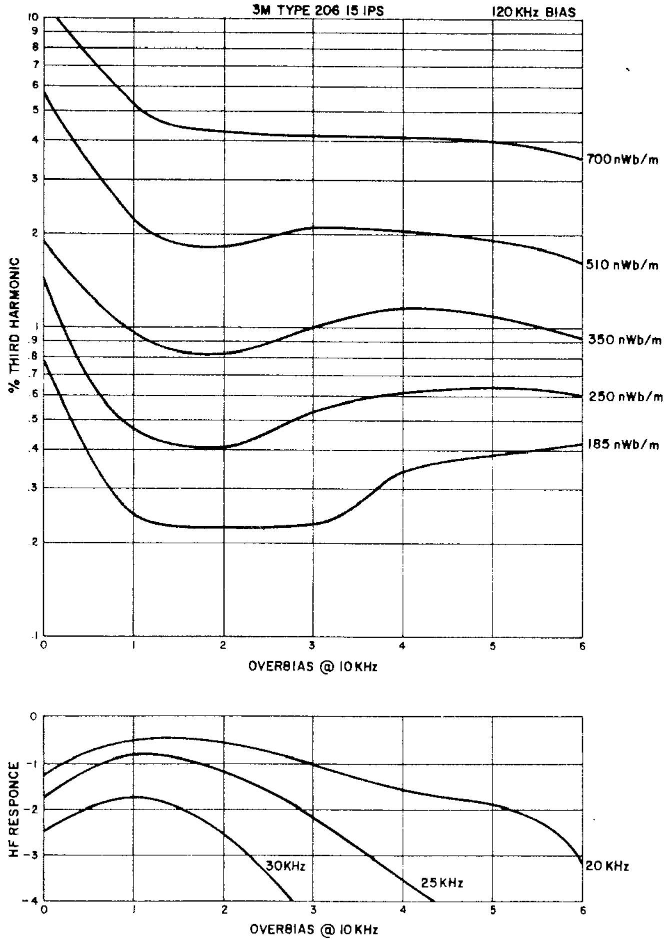

3M TYPE 206 15 IPS
120KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
OVERBIAS @ 10KHz
700nWb/m
510nWb/m
350nWb/m
250nWb/m
185nWb/m
HF RESPONCE
0
-1
-2
-3
-4
30KHz
25KHz
20KHz
OVERBIAS @ 10KHz

FIG. 10

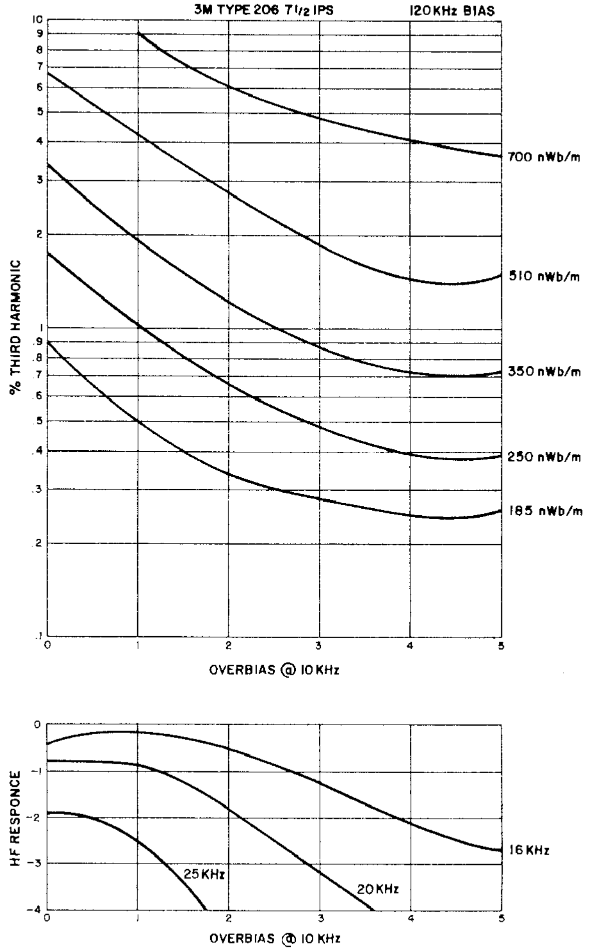

3M TYPE 206 7 1/2 IPS
120KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
OVERBIAS @ 10KHz
700 nWb/m
510 nWb/m
350 nWb/m
250 nWb/m
185 nWb/m
HF RESPONCE
0
-1
-2
-3
-4
25KHz
20KHz
16KHz
OVERBIAS @ 10KHz

FIG. 11

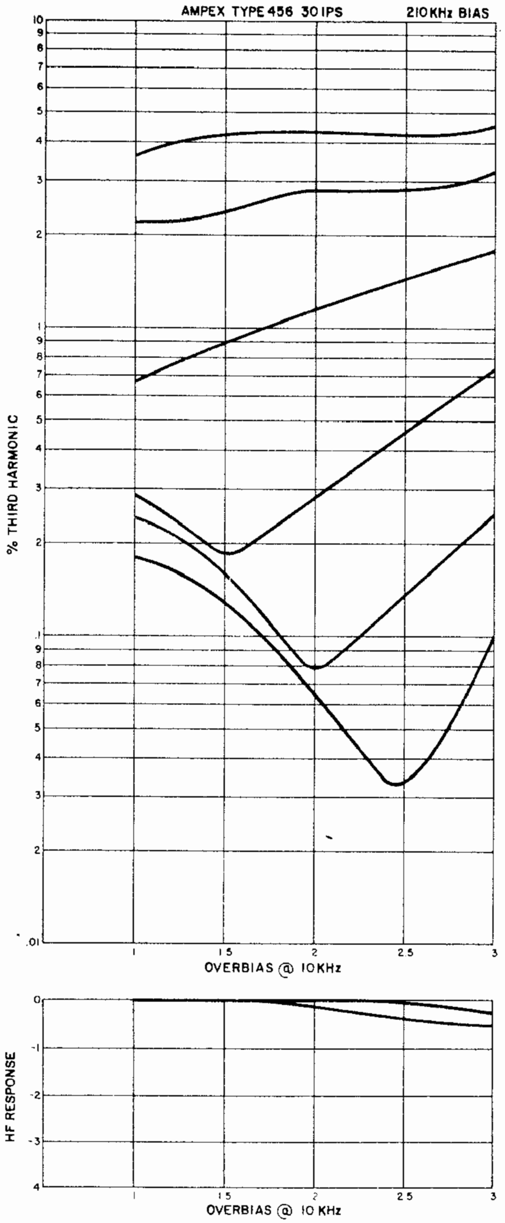

AMPEX TYPE 456 30 IPS
210KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
.01
OVERBIAS @ 10KHz
1
1.5
2
2.5
3
HF RESPONSE
0
-1
-2
-3
4
OVERBIAS @ 10 KHz

FIG. 12

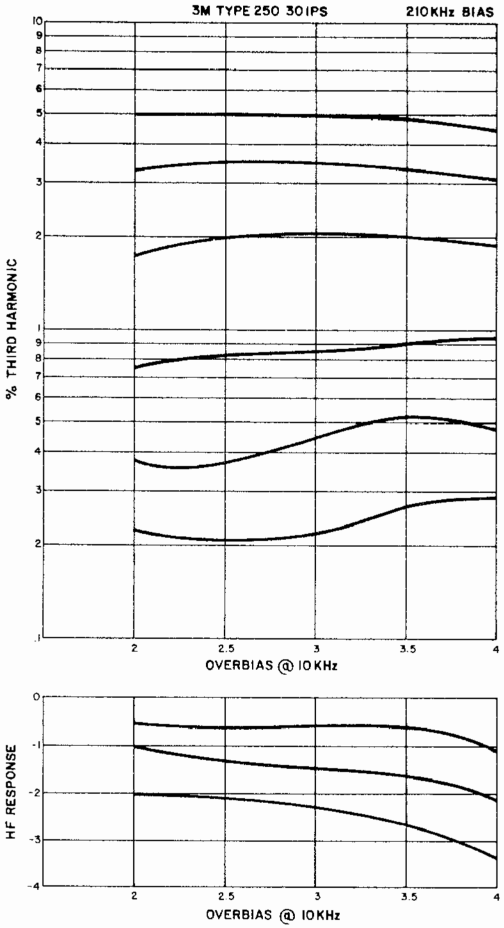

3M TYPE 250 30 IPS
210KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
OVERBIAS @ 10KHz
2
2.5
3
3.5
4
HF RESPONSE
0
-1
-2
-3
-4
OVERBIAS @ 10KHz

FIG. 13

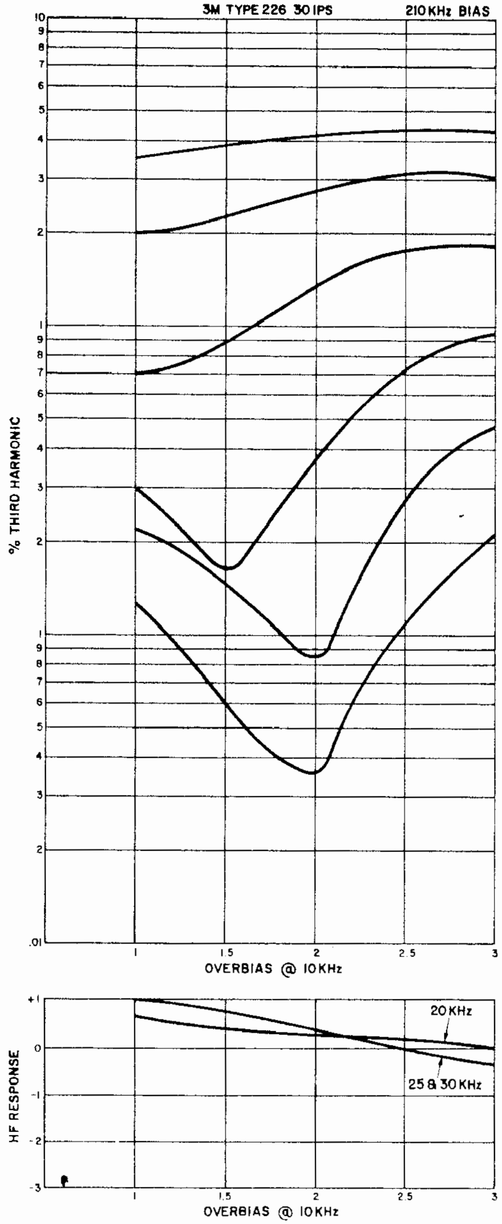

3M TYPE 226 30 IPS
210 KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
.01
OVERBIAS @ 10 KHz
1
1.5
2
2.5
3
HF RESPONSE
+1
0
-1
-2
-3
20 KHz
25 & 30 KHz
OVERBIAS @ 10 KHz

FIG. 14

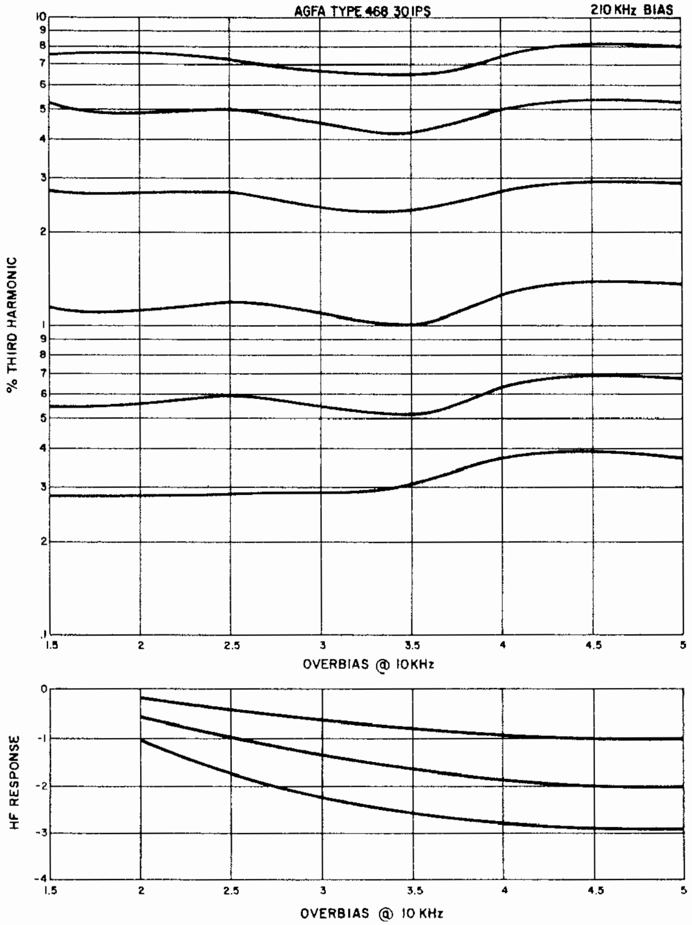

AGFA TYPE 468 30 IPS
210 KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
1.5
2
2.5
3
3.5
4
4.5
5
OVERBIAS @ 10 KHz
HF RESPONSE
0
-1
-2
-3
-4
OVERBIAS @ 10 KHz

FIG. 15

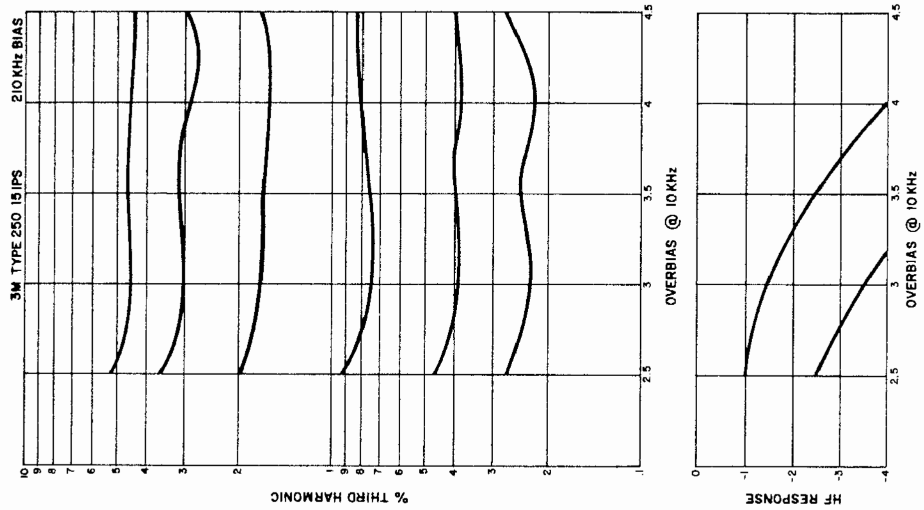

3M TYPE 250 15IPS
210KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
OVERBIAS @ 10KHz
2.5
3
3.5
4
4.5
HF RESPONSE
0
-1
-2
-3
-4

FIG. 17

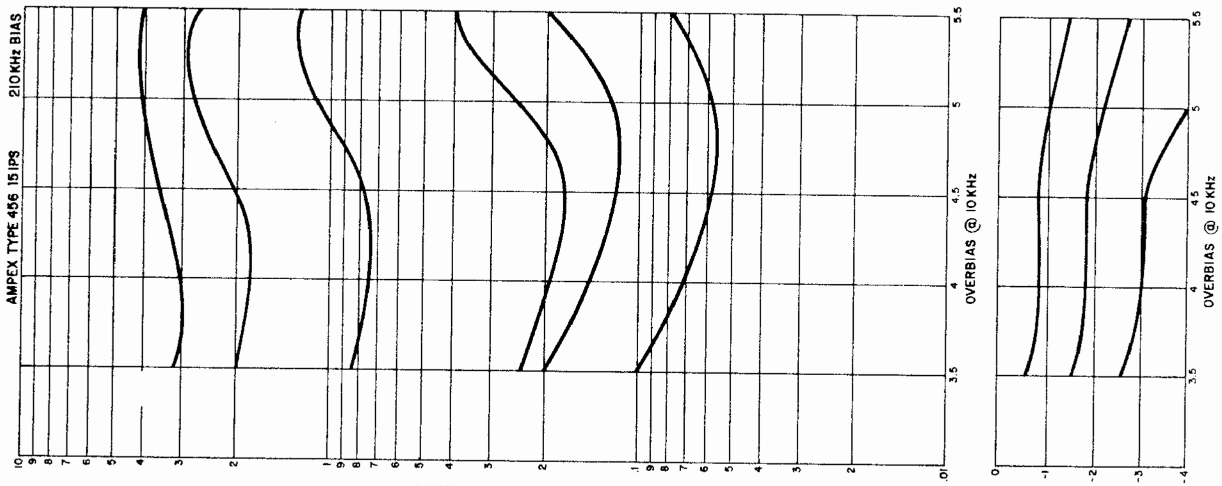

AMPEX TYPE 456 15IPS
210KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
.01
OVERBIAS @ 10KHz
3.5
4
4.5
5
5.5
HF RESPONSE
0
-1
-2
-3
-4

FIG. 16

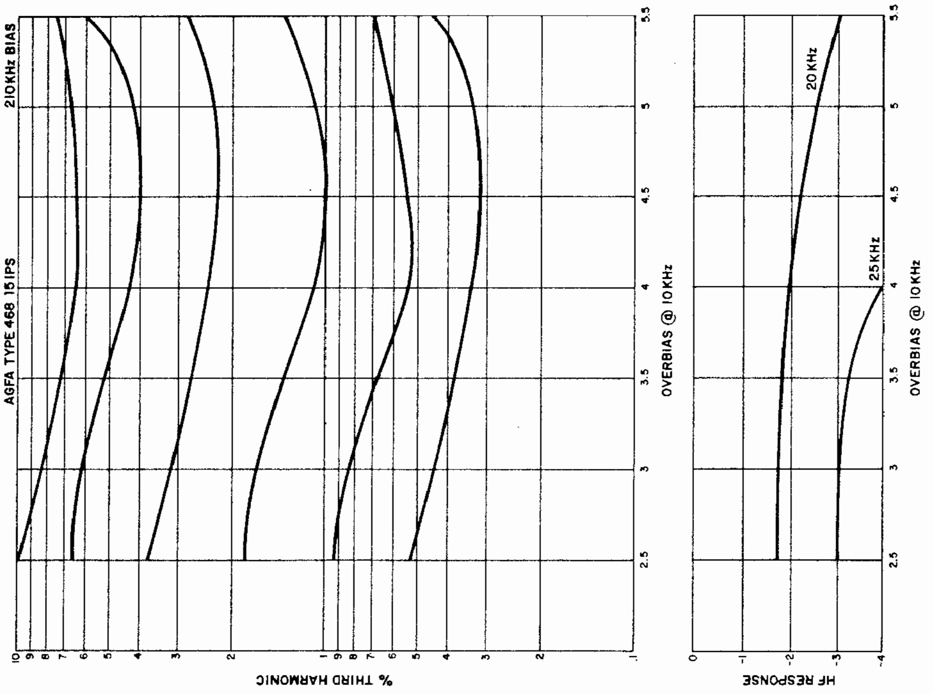

AGFA TYPE 468 15 IPS
210KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
2.5
3
3.5
4
4.5
5
5.5
OVERBIAS @ 10KHz
HF RESPONSE
0
-1
-2
-3
-4
20KHz
25KHz
OVERBIAS @ 10KHz

FIG. 19

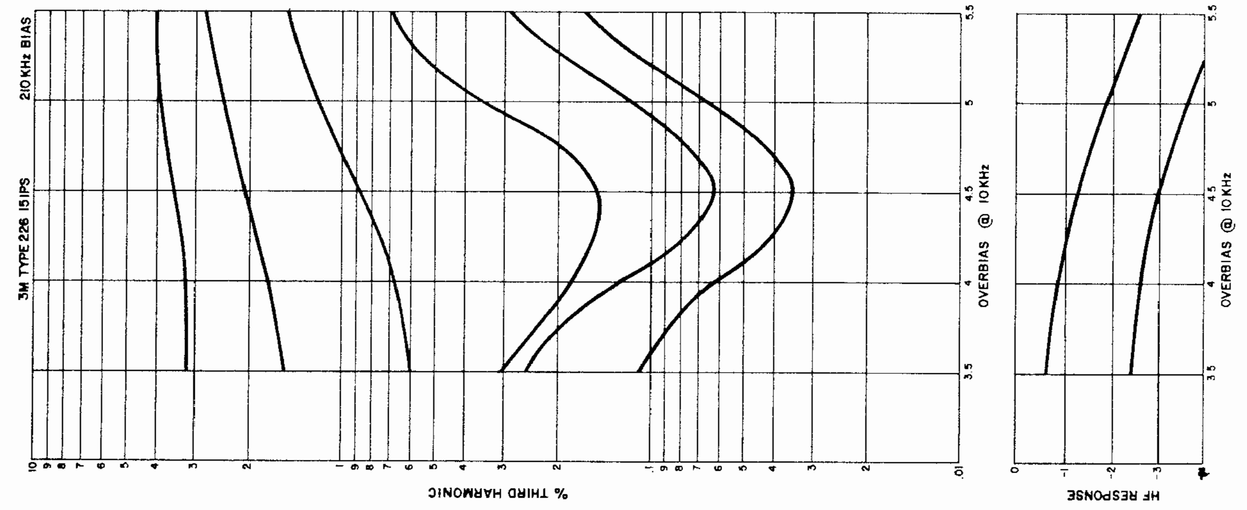

3M TYPE 226 15IPS
210KHz BIAS
% THIRD HARMONIC
10
9
8
7
6
5
4
3
2
1
.1
.01
3.5
4
4.5
5
5.5
OVERBIAS @ 10KHz
HF RESPONSE
0
-1
-2
-3
-4
OVERBIAS @ 10KHz

FIG. 18

RECORDING TRANSFER FUNCTION

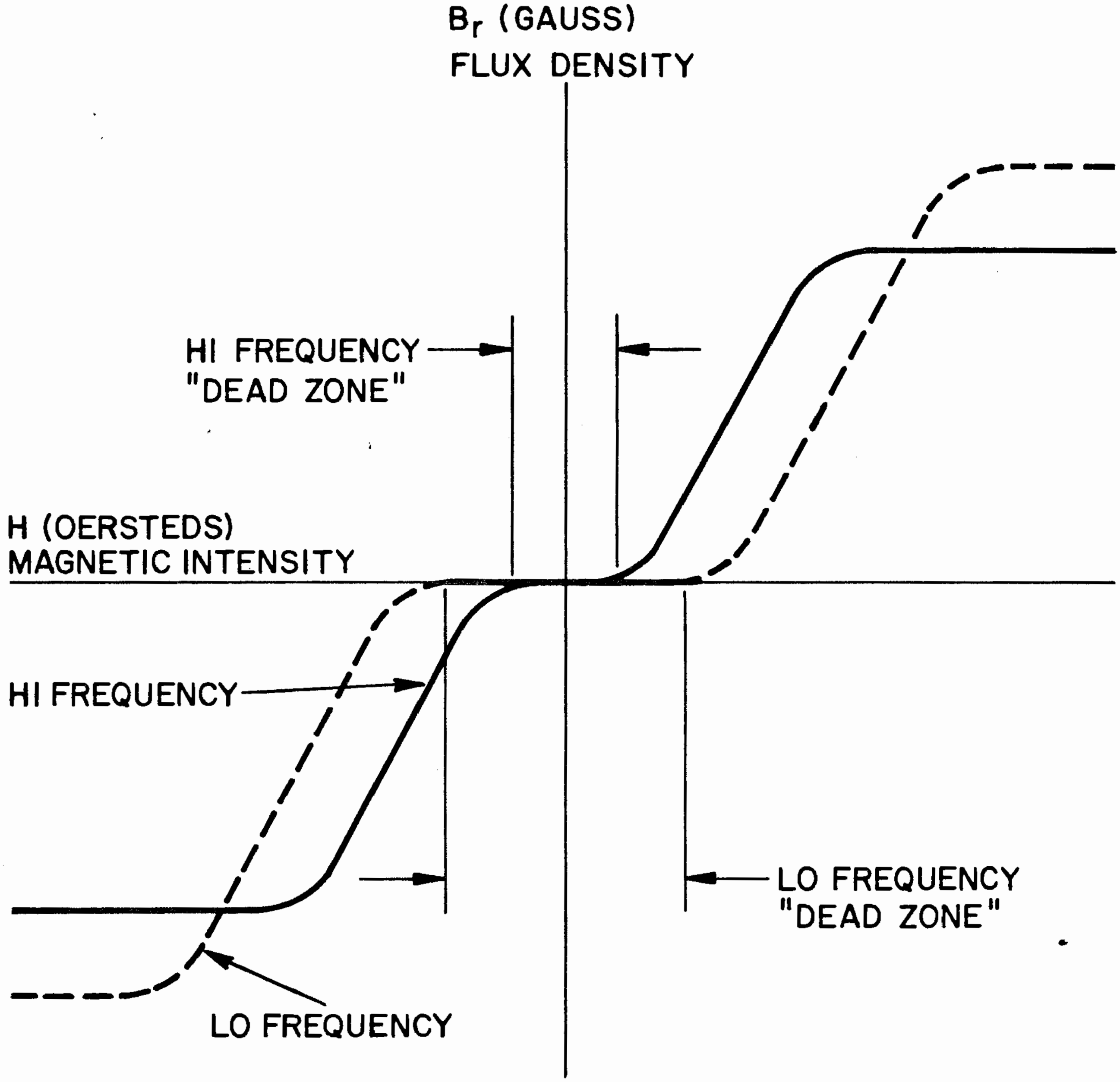


FIG. 20

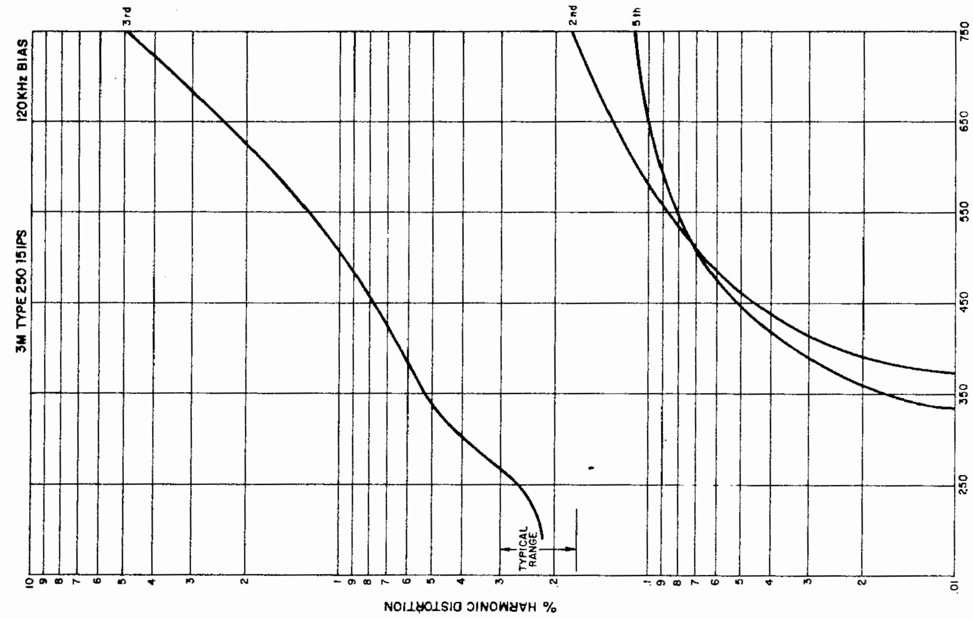

3M TYPE 250 15IPS
120KHz BIAS
3rd
2nd
5th
TYPICAL RANGE
% HARMONIC DISTORTION
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
.01
FLUXIVITY nWb/m
250
350
450
550
650
750

FIG. 22

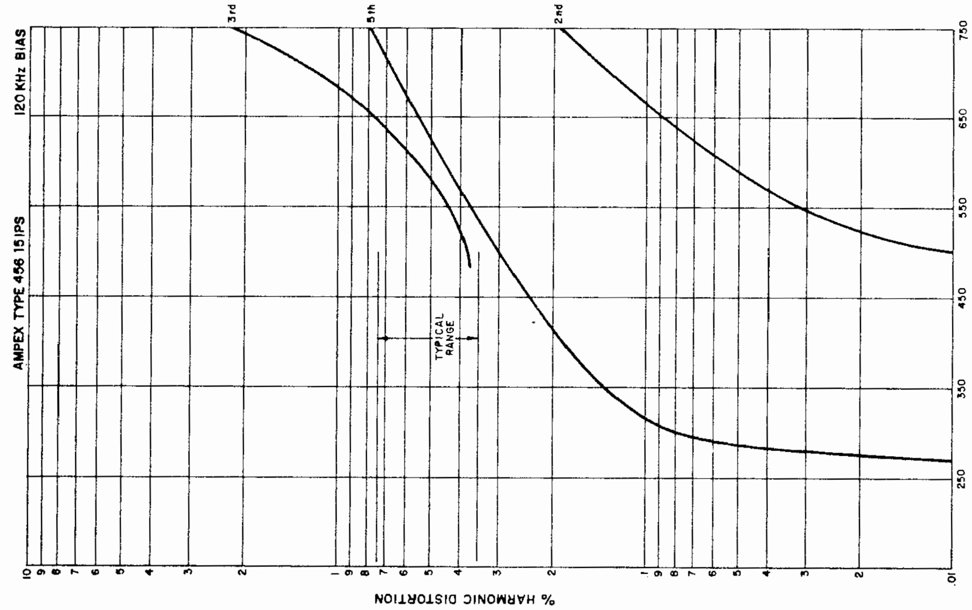

AMPEX TYPE 456 15IPS
120 KHz BIAS
3rd
5th
2nd
TYPICAL RANGE
% HARMONIC DISTORTION
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
.01
FLUXIVITY nWb/m
250
350
450
550
650
750

FIG. 21

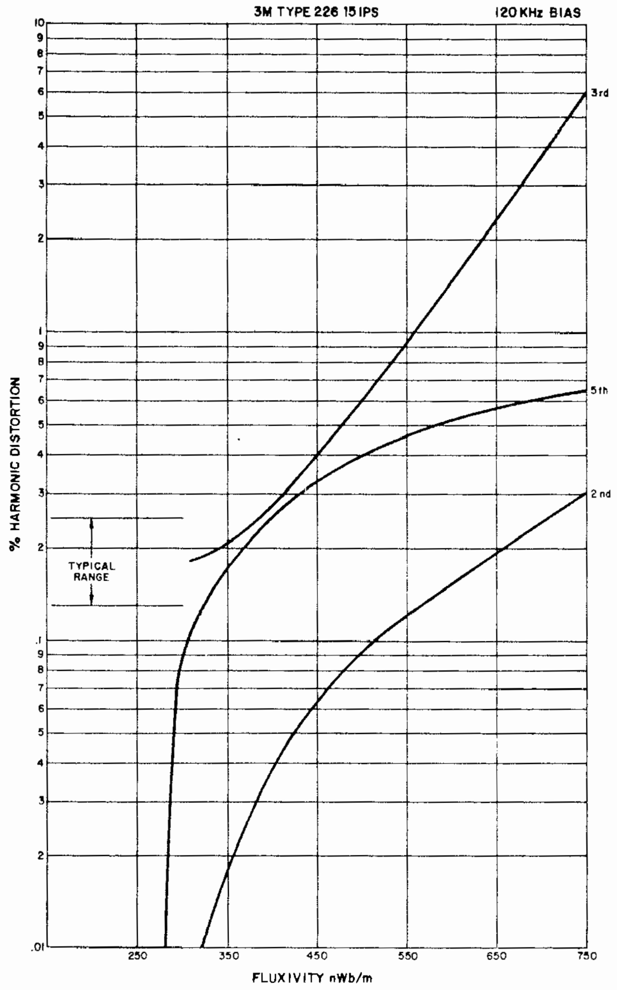

3M TYPE 226 15 IPS
120 KHz BIAS
% HARMONIC DISTORTION
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
.1
9
8
7
6
5
4
3
2
.01
TYPICAL RANGE
3rd
5th
2nd
250
350
450
550
650
750
FLUXIVITY nWb/m

FIG. 23

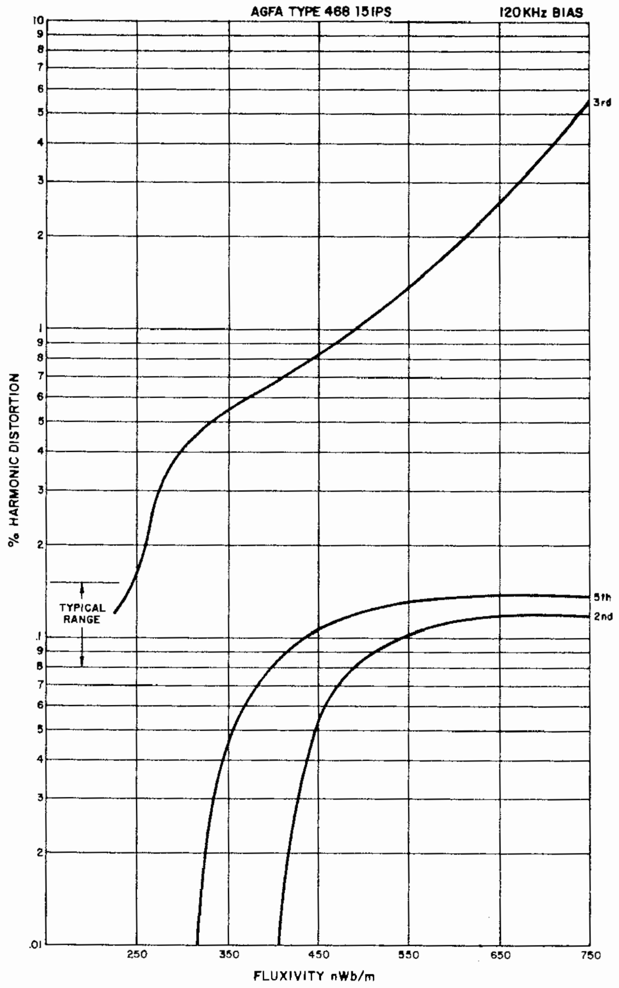
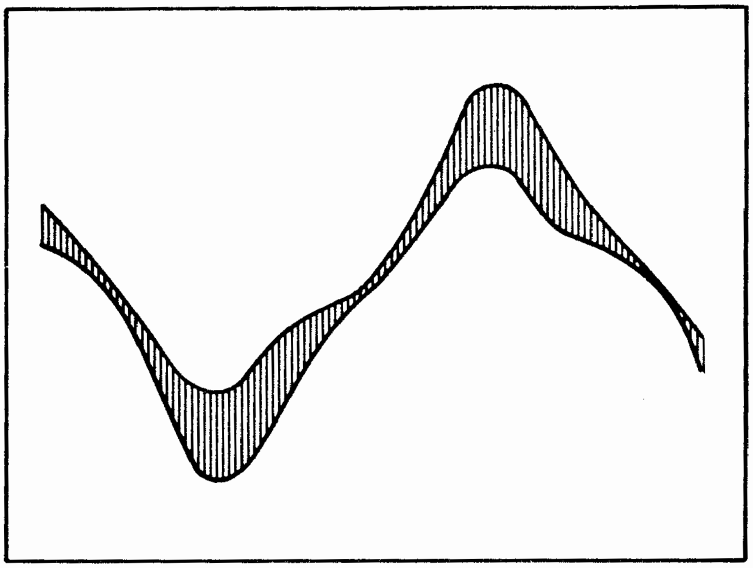
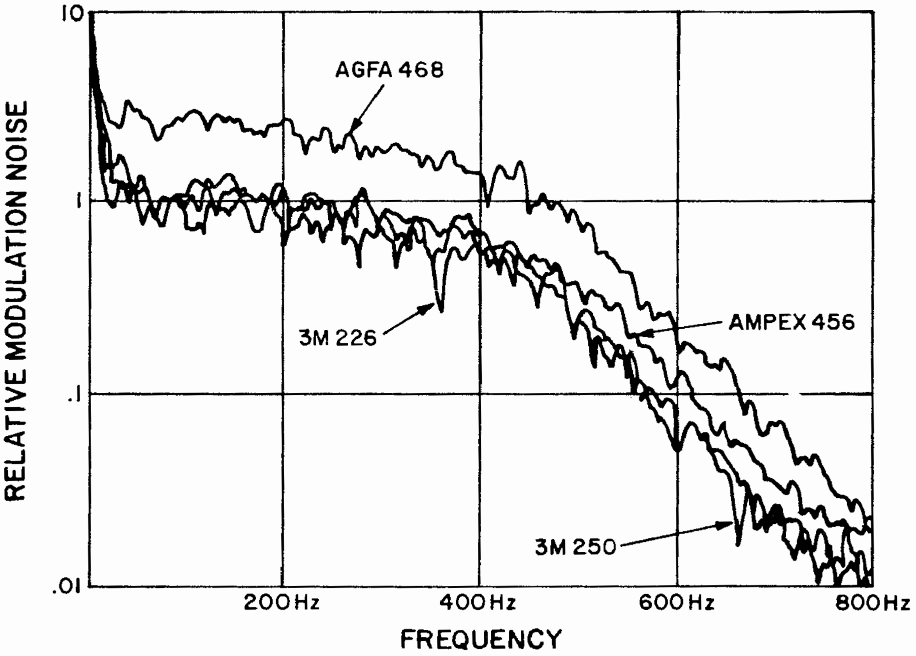

AGFA TYPE 468 15 IPS
120 KHz BIAS
% HARMONIC DISTORTION
10
9
8
7
6
5
4
3
2
1
9
8
7
6
5
4
3
2
.1
9
8
7
6
5
4
3
2
.01
TYPICAL RANGE
3rd
5th
2nd
250
350
450
550
650
750
FLUXIVITY nWb/m

FIG. 24



S.M.P.T.E. I.M. WAVEFORM W/LO FREQUENCY COERCIVITY RELATED DISTORTION

FIG. 25



SPECTRAL ANALYSIS DETECTED MODULATION NOISE

FIG. 26