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AFTAC MAGNETIC TAPE RECORDING STANDARDS
PROJECT VELA-UNIFORM

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PROJECT VELA-UNIFORM
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INTRODUCTION: The almost one hundred participants of VELA-UNIFORM are involved in a cooperative research and development program with one aim: To improve the seismic detection capability for underground nuclear detonations. Such a program necessarily produces a large amount of basic seismic data.

AFTAC has encouraged the use of magnetic tape as a primary recording system for seismic data. These magnetic tape recording standards serve two purposes: (1) they make all data useable by any participant or analysis facility and (2) they provide present and future requirements to tape recorder manufacturers.

The standards contained herein have been approved as a standard for all work on AFTAC VELA-UNIFORM projects.

PART I - BASIC REQUIREMENTS

1. SCOPE

1.1 This standard covers the recording and playback technique, and basic equipment requirements, for the magnetic tape recording of seismic data in the frequency range of 0 to 100 cps. This standard covers only analog recordings, and does not include direct digital recording.

1.2 Tracks have been reserved for time codes. The standards describing the time codes are found in Part II of this document.

2. REQUIREMENTS

2.1 There shall be two general types of analog recording used: direct for timing, audio frequencies, identification, and frequency division multiple of low frequency data; and FM for data.

2.2 Existing hardware shall be standardized to the greatest extent possible.

2.3 Ordinarily, a reel of tape shall carry at least 24 hours of data, for operational reasons.

2.4 IRIG standards 101-57 and 101-60 generally apply.

3. DETAILED STANDARDS

The detailed standards are a summary of information gathered from all participating parties within the program. It is understood that necessary exceptions already in effect in no way affect this document.

3.1 Type

Data recording shall be of two general types:

a. FM multichannel with $\pm$ (plus or minus) 40% center frequency deviation.

b. Frequency division multiplex (such as Zipagram) which can be placed on a direct record channel.

3.2 FM Data Track Performance

a. Frequency response

Frequency response of the FM data tracks shall be not more than one-half db down from the peak response in the following range:

0.3 ips	0-50 cps
0.6 ips	0-100 cps

b. Drift

After one-half hour warm-up, the drift of the FM carrier frequency and gain of a track used for data shall not exceed the following:

Center frequency:	± 1% over 8 hour period
Gain setting:	± 1% over 8 hour period

c. Linearity

The amplitude linearity of the FM data record/reproduce tracks shall be within ± 2% of full scale based on the best straight line.

3.3 Recording Speed

Recording speeds shall be 0.3 ips or 0.6 ips with an accuracy of ± 0.5%.

3.4 Playback Speed

Playback speeds will ordinarily be 0.3, 0.6, 3.6, 30 and 60 ips with an accuracy of ± 0.5%.

3.5 Time Code

Track one of the tape shall be reserved for a digital time code.

3.6 Audio Frequency Channel

The highest number track of the tape shall be used for direct recording of audio frequency voice comments and/or WWV signals. Additional time coding can be applied to this track for local station usage, by using pulse modulated carrier frequencies in the audio range.

3.7 Compensation

Flutter compensation requires the use of one track of the tape for injection of a constant carrier frequency. The compensation oscillators and discrimators shall have the following characteristics:

a. Center frequencies

0.3 ips	240 or 270 cps
0.6 ips	480 or 540 cps

b. Frequency stability

± 1% over 8 hour period

c. Gain stability

± 1% over 8 hour period

3.8 Tape Width

Tape width shall be 1/2" or 1"

3.9 Head Configuration

Per IRIG standard 101-60

3.10 System Signal-to-Noise Ratio

The signal-to-noise ratio of the FM tracks used for data or flutter compensation shall be:

Compensated:	0.3 ips	40 db
Compensated:	0.6 ips	45 db
Uncompensated:	0.3 ips	30 db
Uncompensated:	0.6 ips	35 db

The signal-to-noise ratio shall be measured by comparing the peak-to-peak level of a signal producing 40% carrier deviation with the peak-to-peak noise level throughout the channel band-width. The level of the noise shall be determined by using the maximum value observed during a 40 second interval.

3.11 Reel Size

The reel size shall be 14" maximum with NAB standard hubs.

3.12 Recording Speed/Carrier Frequency Ratios

Recording speed and carrier frequencies shall be as follows (see IRIG standard 101-60):

0.3 ips	270 cps
0.6 ips	540 cps

Playback speed/carrier frequency ratio: 3/2700 inches/cycle

3.13 Channel Assignment

For one inch tape, the number of tracks shall be fourteen, assigned as follows:

#1 *Digital timing channel (leave blank if digital timing not used).

#2-6 incl. Data channels
#7 Flutter compensation
#8-13 incl. Data channels
#14 Voice, WWV, and station timing

For one-half inch tape, the number of tracks shall be seven, assigned as follows:

#1 *If digital timing is used, place it on this channel
#2 Data
#3 Flutter compensation or data
#4-6 incl. Data
#7 Voice, WWV or station timing

* Channel one may be used for data if the time code is combined with the flutter compensation.

4. SUMMARY

A summary of the standards for direct and FM recording is tabulated below, with the addition of requirements for future growth or improvement of equipments or techniques.

	Present Req'ts.	Possible Future Req'ts.
Signal Frequency	0-100 cps	----------
Recording Speed	0.3 & 0.6 ips	0.01, 0.03, 0.06 ips
Playback Speed	0.3, 0.6, 3, 6, 30, 60 ips	0.01, 0.03, 0.06 ips
Timing Channel	See time standard	Digital time code
Voice Channel	Voice, WWV and local timing	----------
Compensation	Flutter	Flutter w/pulse time modulation
Tape width	1/2" and 1"	1/4", 1/2" and 1"
Head Configuration	IRIG	----------
Reel Size	14" Max. NAB hubs	----------
No. of data tracks	11 possible	12 possible
System signal-to-noise ratio, compensated	40 db at 0.3 ips 45 db at .6 ips	70 db.
Uncompensated	30 db at .3 ips 35 db at .6 ips	----------
Recording speed/carrier frequency	3/2700 ips per IRIG 101-60	----------
Uninterrupted recording capabilities	At least 24 hours	31 days

PART II - TIME CODE STANDARDS

1. BASIC REQUIREMENTS:

1.1 The following three types of timing will be recorded simultaneously when possible:

WWV Broadcasts
A Time-Mark Program
A Digital Time Code

1.2 A tape channel is reserved for recording of voice comments and WWV (or other time observatory) broadcasts. This recording is highly important, even though in certain areas reception is not always reliable.

1.3 The following time mark program will be mixed with WWV and voice comments and recorded on that channel:

a. A low-level, precision-frequency, 60-cps tone mixed with audio information.

b. The level of this tone will be raised by a relay contact closure at each time mark. A block diagram is given in Figure 1 with a schedule of time marks.

The time-mark program is suitable for timing of visible short-period seismograms, as illustrated in Figures 2 and 3. The following are the maximum permissible errors for the time-mark program when observed prior to recording:

60 cps -

(1) Keep time to within - 0.1 second per week (approximately 1 part in 10^7).

(2) Keep time during any 1-hour period to within $\pm$ 10 milliseconds.

(3) Random variation of period of tone (jitter) as measured at zero-crossings must not exceed 5 milliseconds (peak-to-peak) when observed for any 1-minute period.

Time Marks

(1) Duration of:
10-second marks - 125 $\pm$ 10 milliseconds
5-minute marks - 500 $\pm$ 50 milliseconds
1/2 and 1-hour marks - 1000 $\pm$ 100 milliseconds

(2) Cyclic variation (scatter) of time marks from linear 10-second divisions not to exceed $\pm$ 5 milliseconds

2. DIGITAL TIME CODE

The digital time code follows the general format of the IRIG codes with two slight modifications which permit the code to be read more easily by humans and machines. Figure 4 illustrates the format selected.

2.1 Time Frame - The Time Frame consists of 60 pulses and contains all the information necessary to identify the time to the nearest minute without reference to other frames or the use of interpolation. Each Time Frame is separated from its neighbor by two successive wide pulses, R and P_0. The Time Frame repeats each minute, adding a new increment of one minute to its coded information. The pulse repetition rate is 1 pps.

2.2 Reference Mark - The last pulse of the Time Frame, R, is used as a reference mark that signifies the end of frame. Its duration is 0.8 seconds. When recorded on a visible record, R and P_0 together make a readily identifiable "1-minute mark." (See Figure 5.)

2.3 Position Identifiers - The Time Frame is divided into six equal parts of 10 seconds by the Position Identifiers, "P_0 through P_5". The duration of the Position Identifiers is 0.8 seconds. The onset of the P_0 pulse is the "on-time" point for the following time frame. The start of the P_0 through P_5 pulses is the on-time point for the 10-second divisions, and when viewed on a visible record, are readily identified as "10-second marks."

2.4 Data Bits - The next eight pulses following each position identifier are used for data. Each pulse represents a binary digit (bit) and has a duration of either 0.2 seconds or 0.5 seconds depending on its value of either "zero" or "one", respectively. The beginning of each pulse in the Time Frame is the on-time point for that 1-second division. On a visible record these divisions are readily identified as "1-second marks."

2.5 Decimal Digits - The next eight bits following a Position Identifier comprise two binary-coded decimal (BCD) digits, with a weighting of 8-4-2-1. (This weighting is reversed from the IRIG format (1-2-4-8) to permit the visual observer to see and write down the numbers in a normal manner, i. e., highest significance to the left as viewed. A decoding machine will operate as easily with one weighting as the other). Taken in groups of four bits, the sum of the numbers (8-4-2-1) for which a "one" is present makes a decimal digit according to the following table:

DECIMAL	BCD			
	8	4	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

As shown in Figure 4 the format always will contain "zeros" in the locations that are impossible, e. g., 800's and 400's of days, and in the unused locations (the ninth bit). The format provides a total of 12 decimal digits which are assigned as shown in Figure 4.

2.6 Identification and Control - The last four decimal digits of the Time Frame are used for station (or data block) identifications and control functions. The first three digits following P_4 are reserved for station or data block number and the last digit is reserved for optional arbitrary use. Three-digit station or data-block numbers will be assigned to VELA-UNIFORM participants by AFTAC upon request.

2.7 Flag Bit, F - The ninth bit following the position identifiers is unused except in the Identification and Control Section of the Time Frame. Bit 49 is reserved for signifying an abnormal condition in the data recording format. In a normal condition the Flag Bit is "zero", and in an abnormal condition it is "one".

2.8 Permissible Carrier Frequencies - Any of the following carrier frequencies may be used for recording the Time Code on magnetic tape.

(a) 10 cps - For general purpose use where the bandwidth of the recorder does not exceed that needed for earthquake signals in the range of 0.01 to 10.0 cps.

(b) 100 cps - For general purpose use primarily for signal-plus-bias recording systems.

(c) 60 cps - For use where bandwidth permits and precision frequency 60-cps is available from the station timing system.

(d) 240 cps - For use in FM recording where the carrier is used as a reference tone for tape-speed compensation in lieu of the normal 270-cps center frequency for 0.3 ips (see Magnetic Tape Standards for VELA).

(e) 480 cps - Same as (d), above, except in lieu of 540-cps center frequency for 0.6 ips.

The carrier is used to determine, by vernier methods, time to finer resolution than that provided by the encoded data bits. For example, if both zero-crossings of a 10-cps carrier are detected, the resolution of the decoded time is 50 milliseconds. Higher frequency carriers will provide better resolution (but not necessarily better accuracy).

If the bandwidth and cross-talk characteristics of the magnetic-tape recorder are sufficient, a square-wave carrier may be used. For example, VELA standards require 0-50-cps bandwidth on 0.3-ips FM recorder, and a 10-cps square-wave carrier will be reproduced with reasonably good fidelity. Use of a square-wave carrier may increase the precision of timing and reduce the cost of the digital time-code generator.

2.9 Long-Period Member - While the Digital Time Code described above is adequate for timing of both short-period and long-period seismic data, special long-period magnetic-tape recorders may be developed having bandwidth characteristics insufficient to record and reproduce the short-period code frequencies. The long-period member of the VELA Standard Time Code is identical to the short-period member except:

All repetition rates are divided by 60

All time durations are multiplied by 60

All bits in the "minutes" group are set to zero

An appropriate carrier frequency must be chosen.

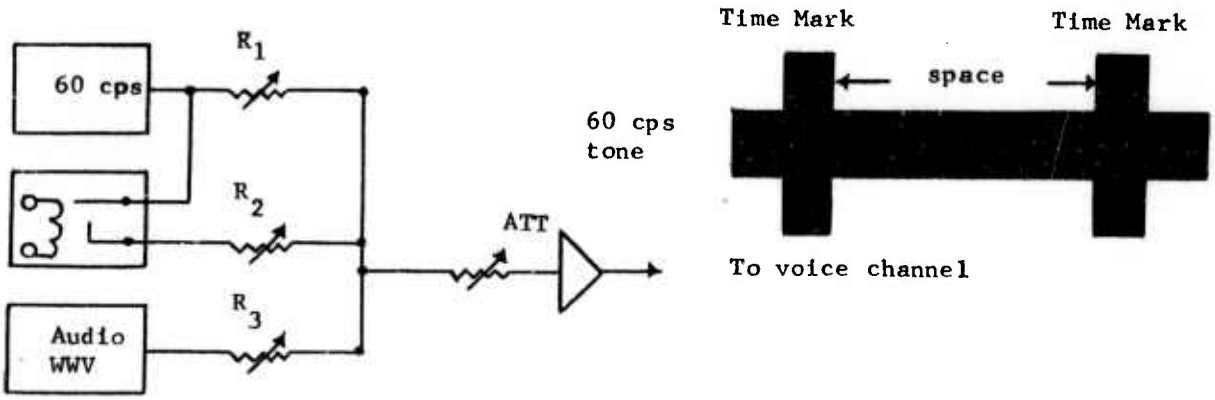
The result is:

A new time frame occurs each hour with R and P_0 denoting "hour-marks"

P_0 through P_5 are "10-minute marks"

The individual pulses are "1-minute marks"

BLOCK DIAGRAM



1. Adjust R_1 and R_2 for approximately 3:1 time-mark-to-space amplitude ratio.
2. Adjust R_3 for approximately 1:1 time-mark-to-audio amplitude ratio.
3. Adjust ATT for desired recording level.

SCHEDULE OF TIME MARKS

1. 1/8 second (125 millisecond) relay closure every 10 seconds except on the minutes.
2. 1/2 second (500 millisecond) relay closure every 5 minutes except on the half-hours.
3. 1 second relay closure every half-hour except on the hours.
4. 1 second closed, 1 second opened, and 1 second closed (double 1 second mark) every hour.

Figure 1. BLOCK DIAGRAM AND SCHEDULE FOR TIME - MARK PROGRAM - VOICE CHANNEL MIXING

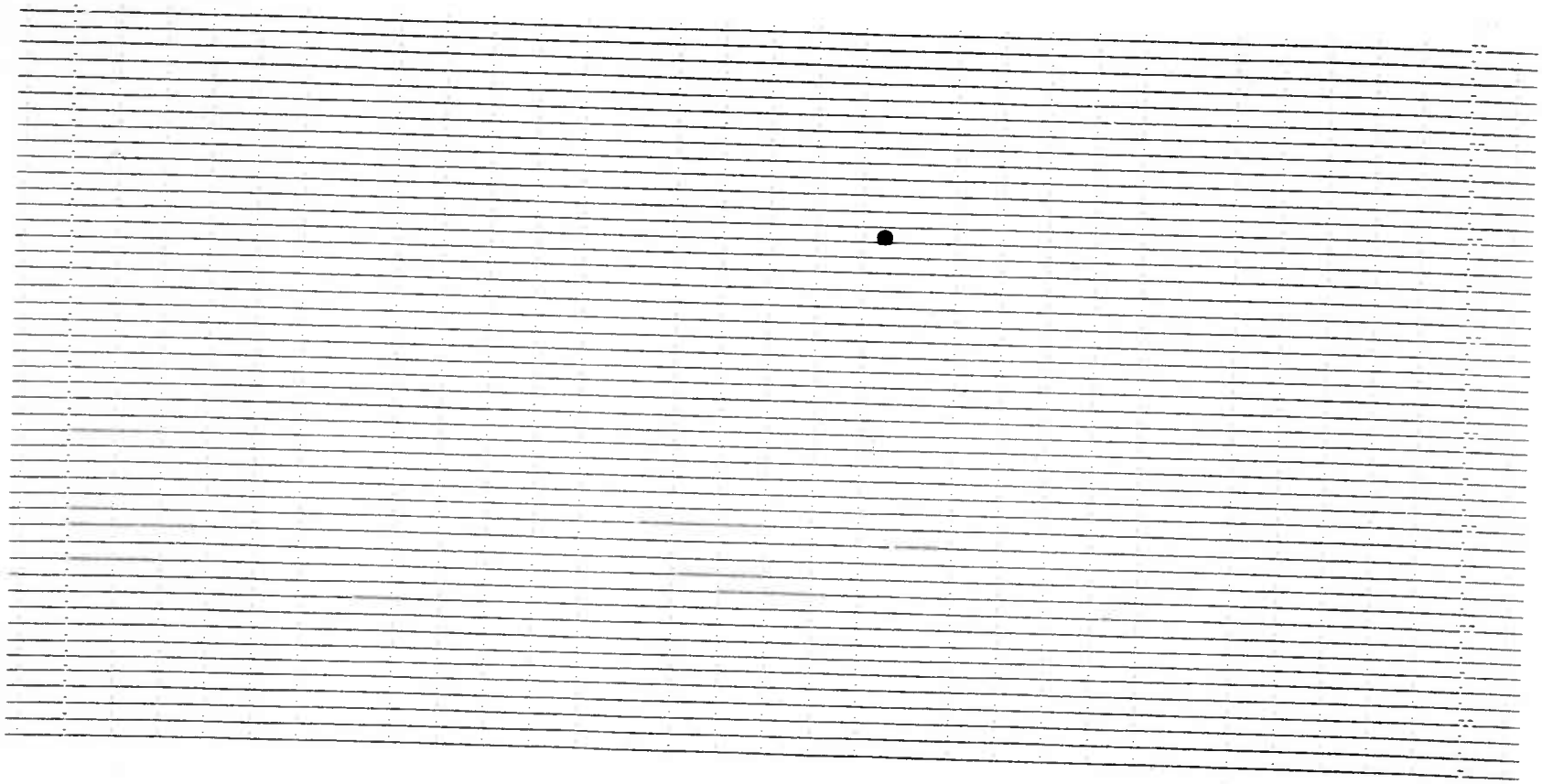


Figure 2. TIME MARK PROGRAM

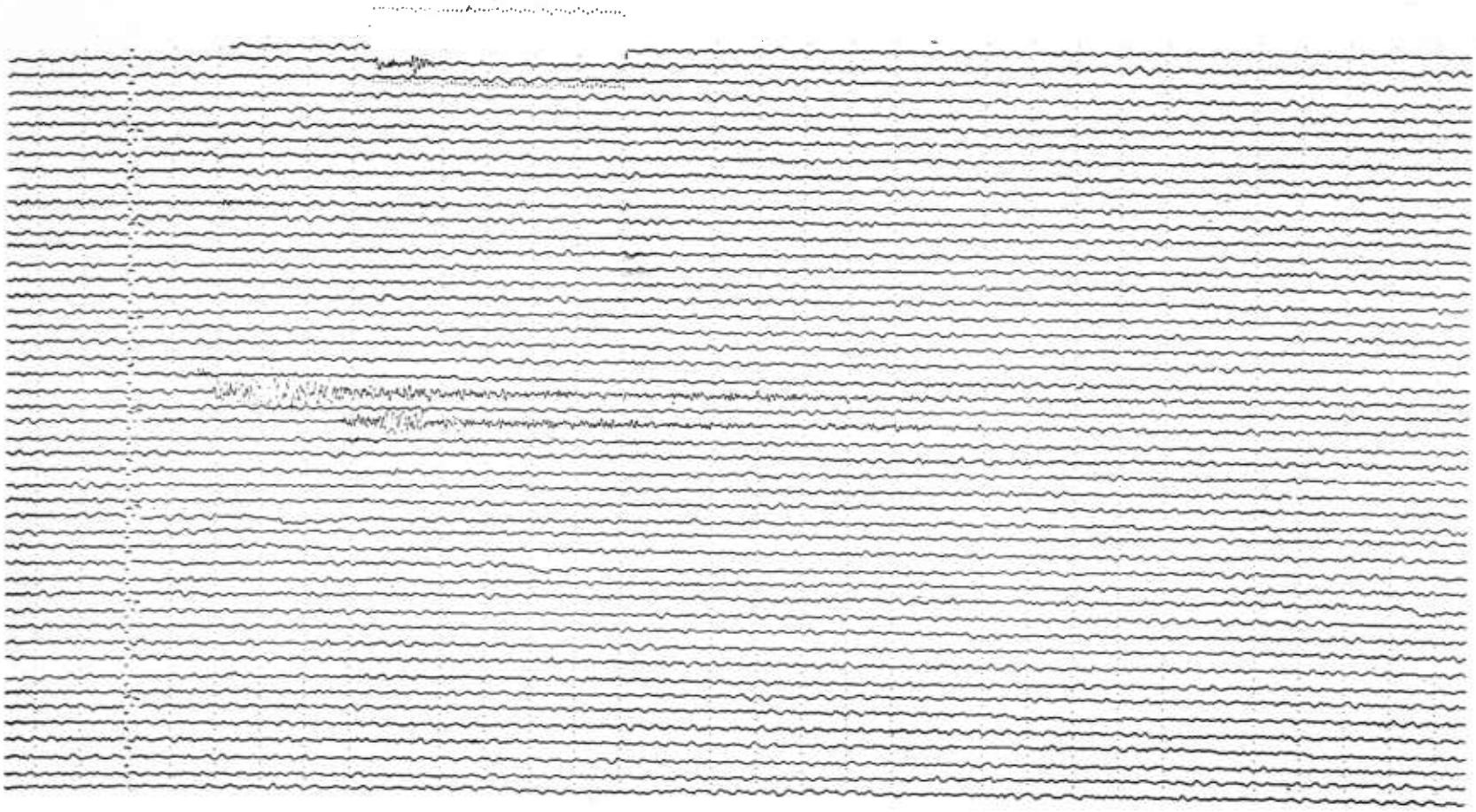
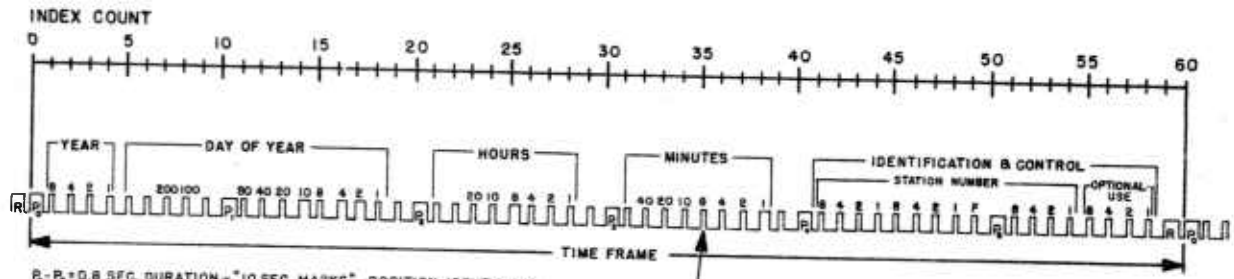


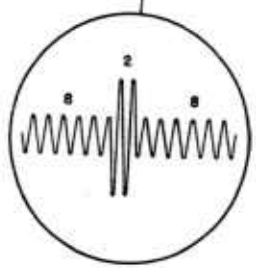
Figure 3. TIME MARK PROGRAM MIXED WITH DATA



P_0-P_5 = 0.8 SEC. DURATION - "10 SEC. MARKS" - POSITION IDENTIFIERS
R = 0.8 SEC. DURATION - "END OF FRAME MARK" - REFERENCE
R & R_1 DENOTE "1 MINUTE MARK"
BINARY CODED DECIMAL BITS - "ONE" = 0.5 SEC.
"ZERO" = 0.2 SEC.

UNUSED BITS = 0.2 SEC.
CLOCK RATE (BIT RATE) = 1 PPS
CLOCK INTERVAL = 1 SEC.
TIME FRAME INTERVAL = 1 MIN.
CARRIER FREQUENCY = 10, 60, 100, 240, 480 CPS
ALL DATA FOR "SHORT PERIOD" RECORDINGS.
FOR "LONG PERIOD" MEMBER, DIVIDE BY 60
FLAG BIT - F - DENOTES ABNORMAL RECORDING FORMAT
WHEN VALUE IS "ONE" (SEE INDEX COUNT 49)

TIME DECODED READS:
YEAR = ZERO
DAY OF YEAR = 16
HOURS = 8
MINUTES = 1



TYPICAL MODULATED CARRIER

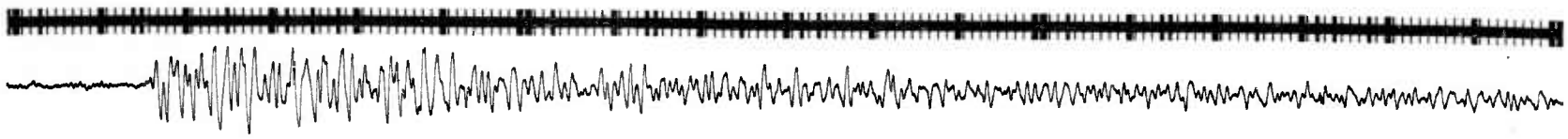
VELA STANDARD TIME CODE FOR USE WITH MAGNET TAPE RECORDING.
(ADAPTED FROM IRIG RECOMMENDED STANDARD FOR RANGE TIMING SIGNALS)

FIG. 4

YEAR - 2
DAY - 18
TIME - 08:49

YEAR - 2
DAY - 18
TIME - 08:50

YEAR - 2
DAY - 18
TIME - 08:51



HELICORDER RECORDING OF OUTPUT OF TIME CODE GENERATOR

AND SHORT - PERIOD SEISMOGRAM

Figure 5.

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Users of these standards are encouraged to contact AFTAC (TD-1) with their comments and questions.