A MICROPROCESSOR

FAULT ANALYZER

By

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Introduction

This paper describes the requirements that will permit a standardized computer analysis of fault waveforms and events. The ultimate object of this analysis is to present the fault data in a more usable form. The presentation of fault data should be in the form of both waveforms and printed values of AC magnitudes along with the time sequence of events, including time to clear and reclose during a fault clearing and reclosing.

Printed information can provide data for fault analysis and problem identification, but cannot substitute for a transient analysis of waveforms and the detection of incipient failures.

Waveform data should be analyzed so that preventive maintenance may be performed prior to the destruction of apparatus.

The printed data suggested in this paper provides for the most urgent information, while transient waveforms may be reviewed for incipient failures on a routine basis.

Printed Data

Figure 1 illustrates typical fault waveforms and "broken line" events traces from a present-day fault recorder. The top three traces are potential traces and the fourth trace is neutral current. The fifth trace illustrates "pips" from an associated SER. The last group of traces are broken-line events, which are either on or off depending on the position of the associated contract.

It is possible to measure the average magnitude of the AC waveforms during a fault and print out a value of that magnitude. It is also possible to establish the clearing time from high-speed fault sensor operations and the time of reclosing from breaker auxiliary contacts. The events traces themselves provide for the time and sequence of various operations. A time trace, not shown in Figure 1, ties all these data together in a time sequence.

Printed data is sufficient to permit a fault analysis to establish the following:

Nature of the fault

Severity

Approximate location

Verify fault studies

In addition, a normal or abnormal clearing may be determined by:

Time to clear

Time to reclose

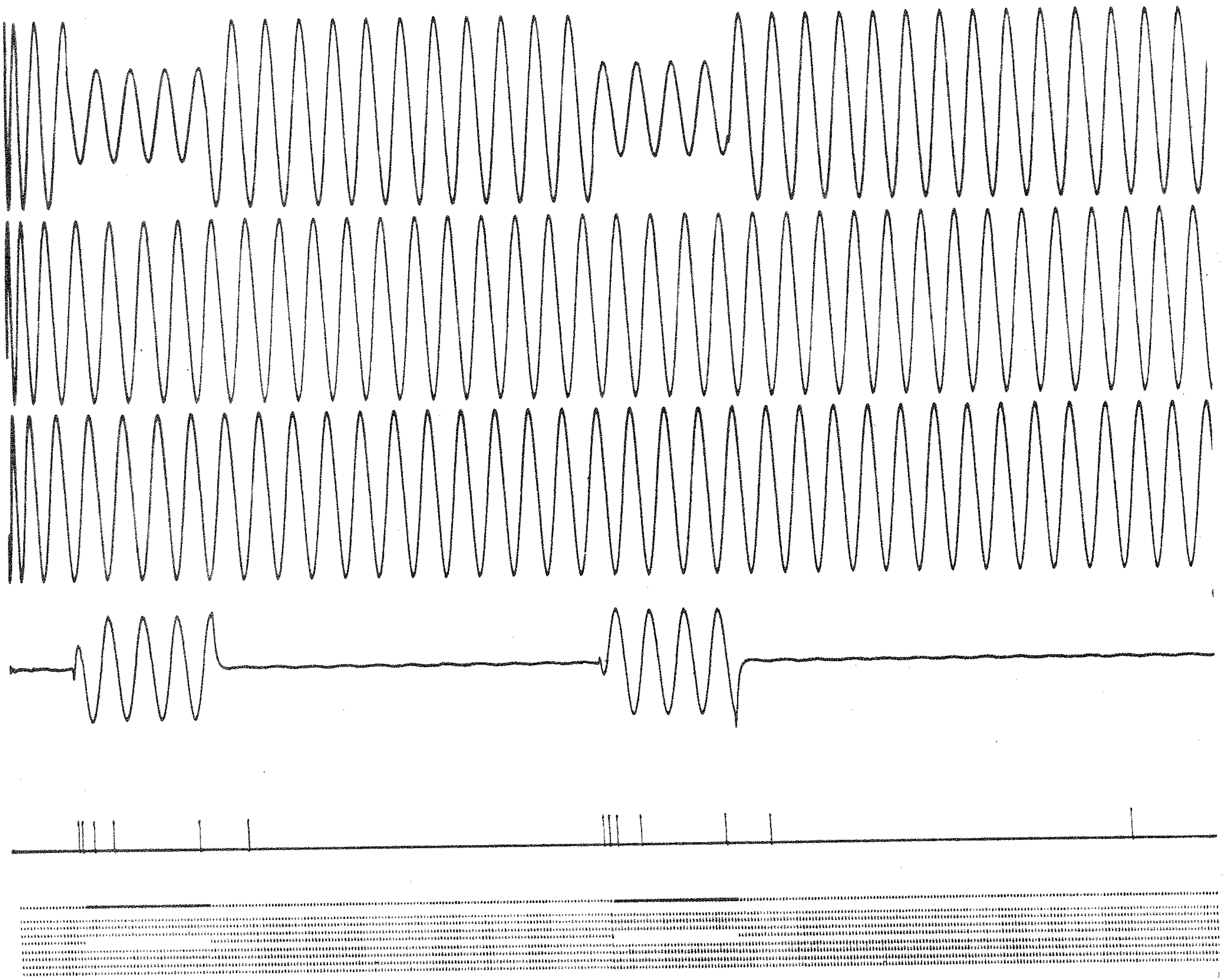

Figure 1- Fault Waveforms and Events

If a clearing was not normal, the problem may be identified by comparing the time of closing or reclose to the time sequence of events from the following:

Sensor events

Trip pulses

Breaker Aux Contacts

Relay operations

Relay test points

The ability to pinpoint a problem in a specific relay scheme or to a specific piece of hardware depends, to a large degree, on how many analog and event quantities are available for analysis. Today, we rely on the relay engineer's skill and imagination in oscillogram analysis of a sparse set of quantities. Microprocessor equipment is economical and permits recording more channels of data on a rigorous basis to permit an analysis by less skilled people or a computer.

A rigorous set of quantities for analysis would be to acquire for each device (line, transformer, bus) the following data:

Analog quantities

3-currents

3-voltages

Carrier transmit

Carrier receive

Events

6 Breaker Aux Contacts

4 trip pulse circuits

2 fault sensors ($3I_o$ and negative sequence)

20 events for relay targets and test points

<u>Waveform Data</u>

The set of quantities suggested for recording also provides for transient waveform analysis. The waveform phenomena that require scrutiny are listed below:

1) Noise due to intermittent connections

2) Noise effect on relay response

3) C.T. and P.T. response

4) Intermittent carrier

5) Restrikes

6) Ferroresonance

7) Change in magnitude of fault current prior to clearing

8) Any unidentified transients on the system

It is significant to realize that waveform records should be examined to the extent that all transients on the system are understood so that they may be disregarded or corrective action taken, depending upon their cause and effect on the system.

Figure 2 is just one example of an incipient failure. This case illustrates loose connections in the drawout fingers of a metering potential transformer.

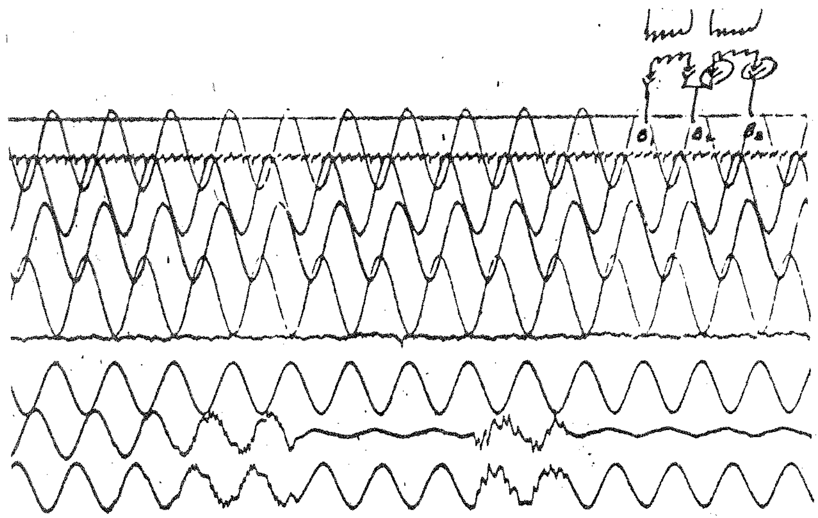

Figure 2 - Loose Connections

Hardware Configuration

The hardware to acquire the quantities outlined should be modular with small data acquisition units (DAU) mounted on the panels associated with each particular device to be monitored and connected to a central data-processing unit (DACON) within the station. The interconnection between each data acquisition unit and the central processing unit should be simple cable to carry time multiplexed data. Figure 3 illustrates the configuration:

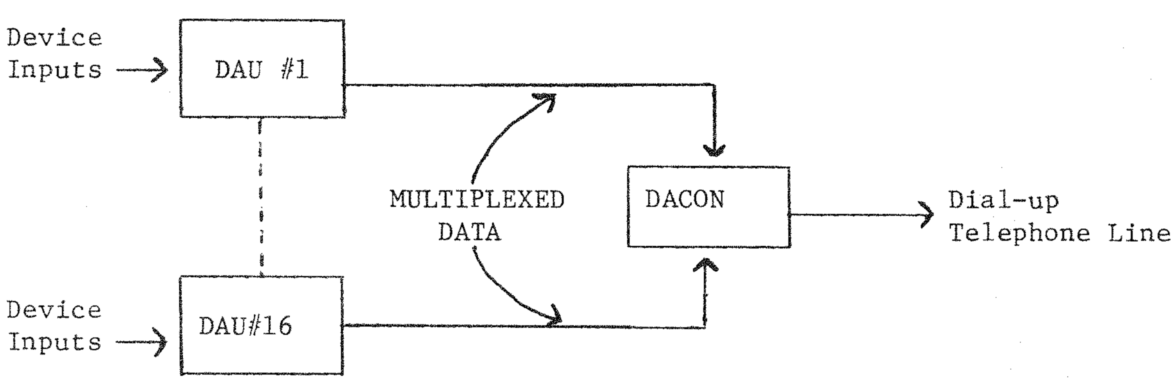

Figure 3 - Hardware Configuration

If the distances between a DAU and the DACON is less than 100 feet, optically isolated and totally shielded communication lines are satisfactory. If distances are greater than 100 feet, fiber optic cables should be employed. This scheme can reduce the cost of equipment wiring and keep the CT and PT wire lengths to a minimum. It is also quite easy to add DAU's when a station is expanded.

It is possible to connect up to 16 DAU's into one DACON and each DAU has 8 channels of analog and 32 events for a capacity of 128 analogs and 512 events.

The DAU and DACON units are only 10-1/2" high and 14" deep and may be mounted in a panel or 19" rack. The cases are made so that the entire unit may be withdrawn from its mounting without disconnecting any wires. The unit may then be taken to the shop for service, where supplies and conditions are more favorable for service work. Figure 4 depicts this structure.

Data is stored in solid-state memory in the DAU's, which eliminates all moving parts so that maintenance is at a minimum. The DAU's are a specialized computer and contain diagnostic routines to disclose particular internal problems and simplify

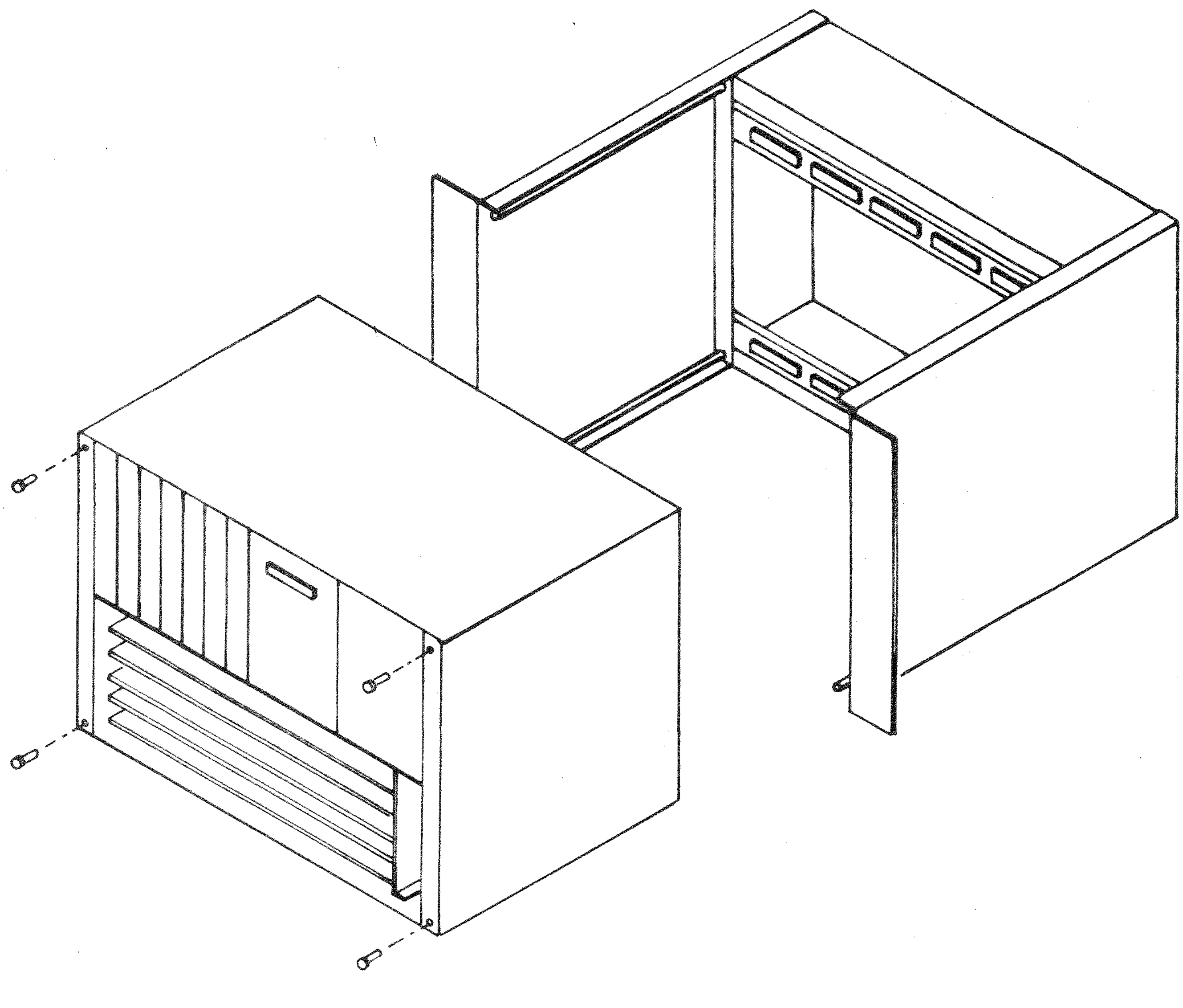

Figure 4 - DAU/DACON Draw-Out Case

trouble-shooting.

Data Capabilities

Each DAU can be fitted with sensors of your choice and can store fault data for 8 analog quantities and 32 events for the time duration (seconds) shown in Table 1.

Freq Response - Hz		
500	1000	1500
150 Sec.	75 Sec.	50 Sec.

Table 1 - Seconds of Fault Data Storage

Table 1 lists the maximum fault data storage. DAU's may be equipped for less storage when the communication rates to a master station are adequate to relieve the DAU memories in sufficient time. Please note that the seconds of fault data correspond to feet of oscillograph paper at 12 inches per second.

The DACON employs the same package as a DAU and employs the same specialized computer as the DAU. The function of the DACON is to provide for up to 16 DAU's and communicate with the master station via a dial-up telephone or other available voice channel.

Fault data is transferred to the master station for one DAU at a time. The time to send a one second fault record to the master station is listed in Table 2.

Baud Rate	Freq Response - Hz		
	500	1000	1500
600	3 Min	6 Min	9 Min
1200	1.5 Min	3 Min	4.5 Min
2400	.75 Min	1.5 Min	2.25 Min

Table 2 - Time to Transmit a One Second Fault Record

Fault data may be acquired for a selectable interval of prefault and during the clearing, dead time and reclosing plus a selectable amount of post-fault. However, storage time and communication time can be reduced if only the clearing and reclose intervals are recorded with appropriate prefault and post-fault on each interval. The equipment may be set up to record data with or without the dead time.

Master Station

The master station employs the same specialized computer as the remote DAU's and DACON's, but in a DACON configured for a master station. In addition, the master station includes a graphics computer with floppy discs and a printer/plotter.

The master station automatically receives alarms from DAU's which have data stored. The operator may then request a summary of the data available. The summarized data includes the following:

1) Time of each fault record in storage

2) Memory remaining at DAU

3) Station and DAU identification

4) Whether or not the device had a trip

The master station operator may then request a printed listing for the particular fault record. This listing includes:

1) Avg current during fault

2) Avg voltages during fault

3) Time to clear

4) Time to reclose

5) Sequence of events on that DAU

The master station operator can also request specific DAU waveform records to be sent and, when satisfactorily received, must command the DAU to cancel that record from storage.

The master station graphics computer with floppy discs is illustrated in Figure 5. This computer is programmed in BASIC and, therefore, allows to user to accomplish various tasks himself if he wishes. One task might be storing tabulated data on a disc for statistical purposes.

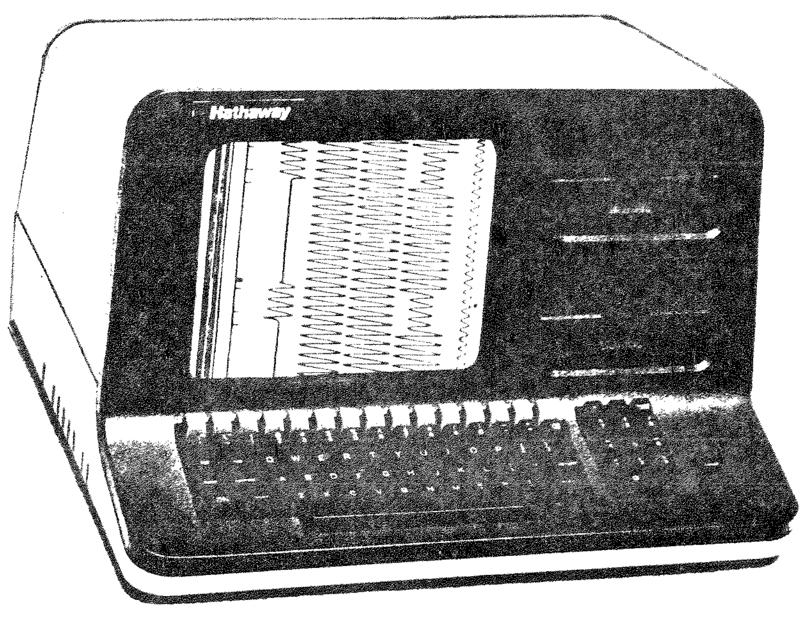

Figure 5 - Graphics Computer

Data received at the master is stored in memory and can be viewed on the graphics computer CRT prior to printing. The "oscillogram" can be scrolled on the CRT to view any section of it. Data may be stored for several DAU's and traces may be selected from any of them to form the desired composite "oscillogram." This composite may then be output on a printer plotter, as illustrated in Figure 6. The composite may also be output to the floppy disc for archival purposes.

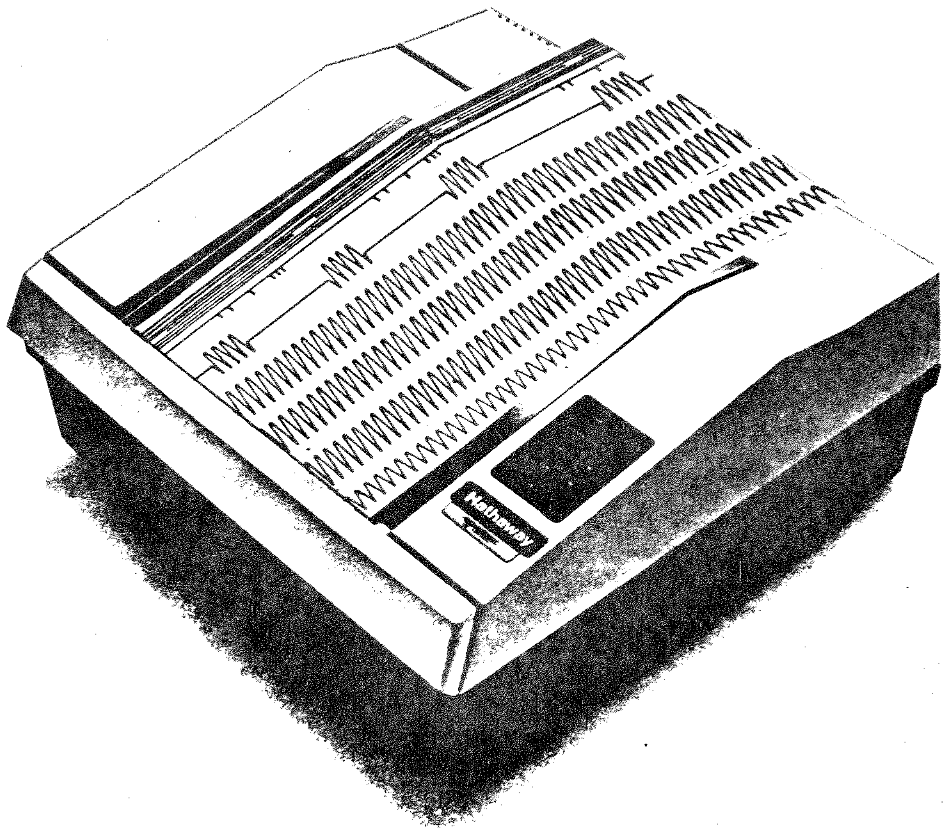

Figure 6 - Printer/Plotter

The traces may be expanded or contracted in amplitude or time base. The extremely low noise of a digital system along with 10 bit resolution (0.1%) and ability to expand small traces permits one to "see" data far out into the system.

The character of the printed record is different from a light beam recording in that it prints out the data in a matrix format. An expanded view of this is illustrated in Figure 7.

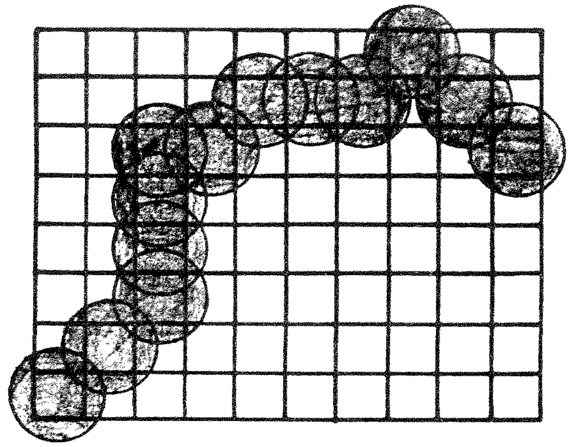

Figure 7 - Printed Matrix

The printer illustrated in Figure 6 employs a matrix of .005" time base and .005" amplitude. The incremental nature is very fine indeed.

The .005" incremental time base results in the effective real-time chart speeed to vary with the number of samples printed for each cycle of 60Hz, as shown in Table 3. The printed samples per cycle of 60Hz need not be the same as the original data acquisition rate. This permits one to select the output chart speed.

Samples per Cycle	Effective Chart Speed	Inches per Cycle	Apparent Sample Rate
17	5 IPS	.08"	1000/sec
50	15 IPS	.25"	3000/sec
100	30 IPS	.50"	6000/sec

Table 3 - Effective Printer Speeds

The actual time to print out a 1 second record after the data is received and stored at the master is two minutes.

Typical matrix printed oscillograms are illustrated in Figures 8 and 9. These are illustrated as full-size oscillograms so that you can see the stepwise appearance. Figure 8 is printed with 50 points per cycle of 60Hz and corresponds to an effective chart speed of 15IPS.

Figure 9 is printed with 100 points per cycle of 60Hz and corresponds to an effective chart speed of 30IPS. It is obvious that the "steps" in the waveforms are less noticeable for the faster chart speeds and smaller magnitudes.

Another characteristic of this type of printout is that fast transients are produced with the same dark trace density as the rest of the trace.

The traces are accompanied with alpha-numeric identification for:

- Station ID
- Device ID
- Trace ID
- Trace calibration factor
- Time trace
- Time and date

The event traces are identified by a tabulation of descriptions at the end of the fault record.

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Figure 8 - 15 inches/sec

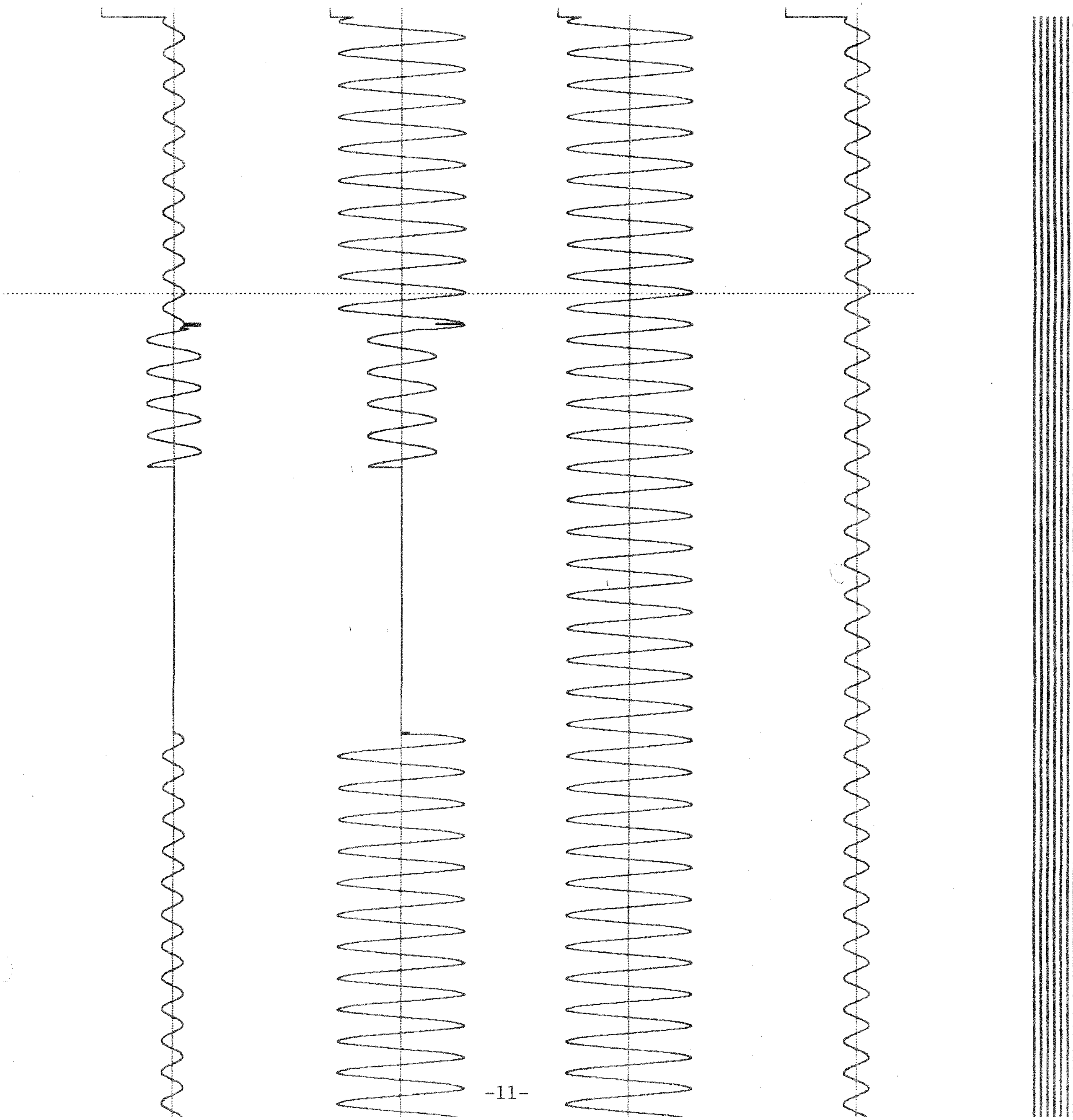

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Figure 9 - 30 inches/sec