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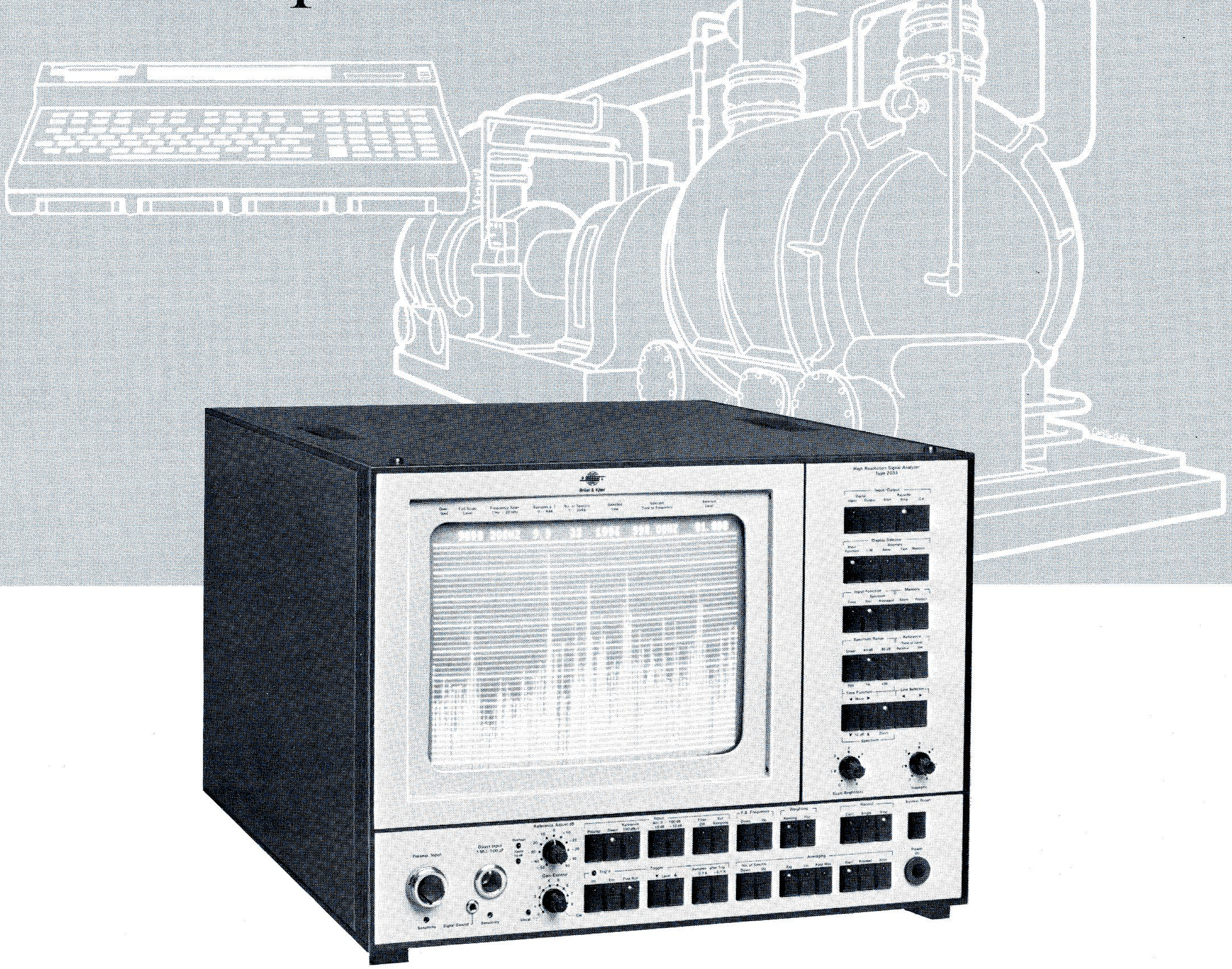
BL 0014 Program Description
for Program BZ 0014

Machine Health Monitoring using FFT Frequency Analyzer Type 2031 or 2033 with a Desk-top Calculator



A Description of BZ 0014 Machine Health Monitoring Program

Introduction

It has been proved that by monitoring the vibration spectrum of a machine at regular intervals, trends can be seen in the spectrum shape which could indicate early breakdown of the machine. With further analysis of the spectra, it is possible not only to predict imminent failure of a machine, but also to pinpoint the cause. This could give a considerable saving in cost, as maintenance could be pre-planned and unexpected machine breakdowns, which cause a loss in production, could be avoided. For further information on machine health monitoring, refer to the B & K Application Notes EFFICIENT MACHINE MONITORING USING AN FFT ANALYZER AND DESKTOP CALCULATOR and GEARBOX DIAGNOSIS USING CEPSTRUM ANALYSIS.

Due to the versatility of the FFT Analyzer and desktop calculator combination in the processing of spectrum data, program BZ 0014 has been developed by B & K as a valuable aid to machine health monitoring in enabling early detection and diagnosis of faults thus saving costly breakdowns.

The program is used in Hewlett-Packard calculator Type 9825 A which is fitted with memory option 002 (24 K bytes), and options 98210 A, one of 98213 A, 98214 or 98216, and interface type 98034 A. A variety of calculations can then be performed on data supplied from a B & K Type 2031 or 2033 FFT Analyzer. Calculator types 9825 S and 9825 B automatically include sufficient memory and the necessary PROM's (though not the interface 98034 A).

Use of the BZ 0014 Programs

A brief outline of the normal procedure adopted when monitoring the performance of a machine is given in Fig.0.1. First a reference

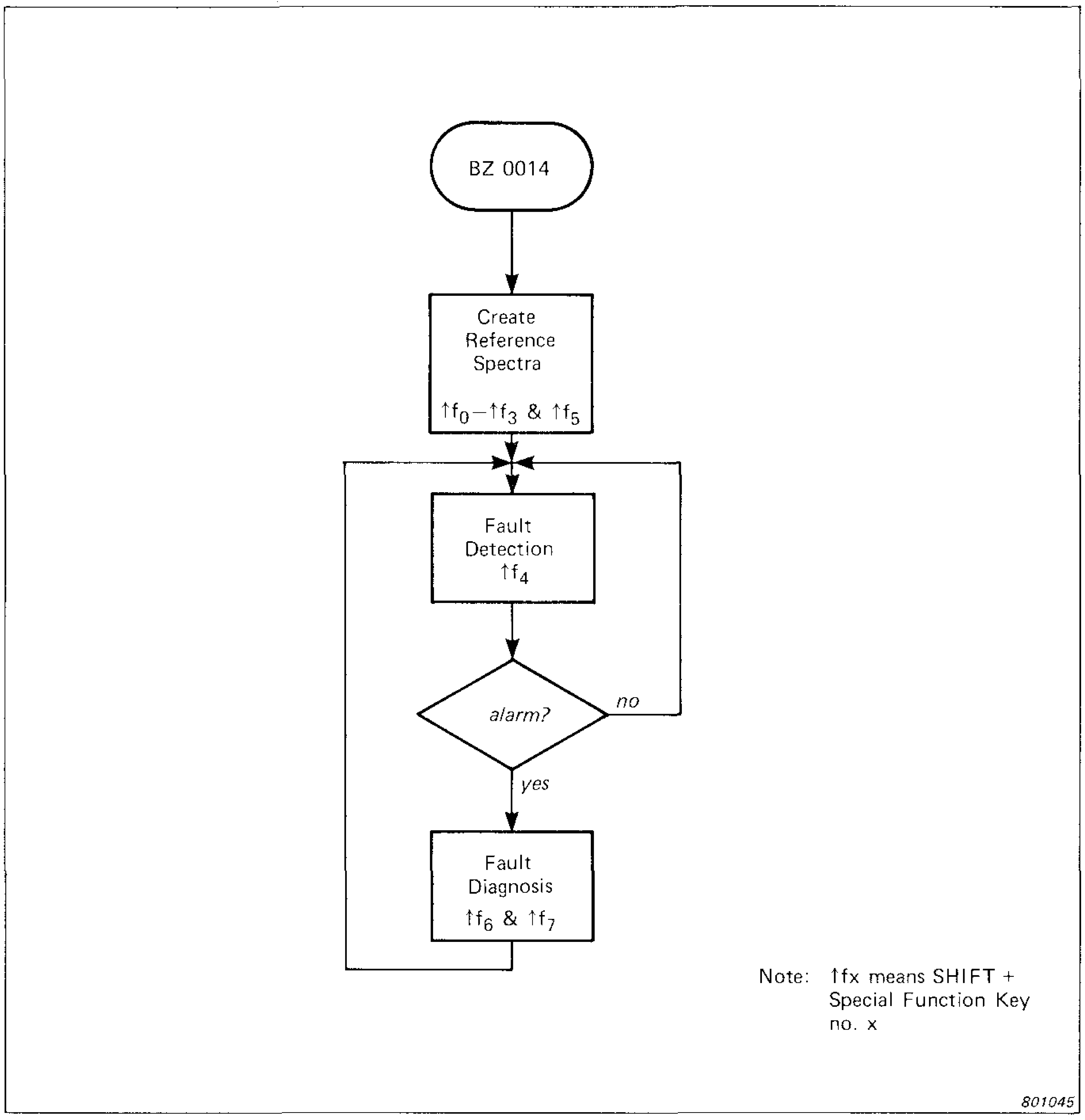


Fig.0.1. Outline of Monitoring Procedure

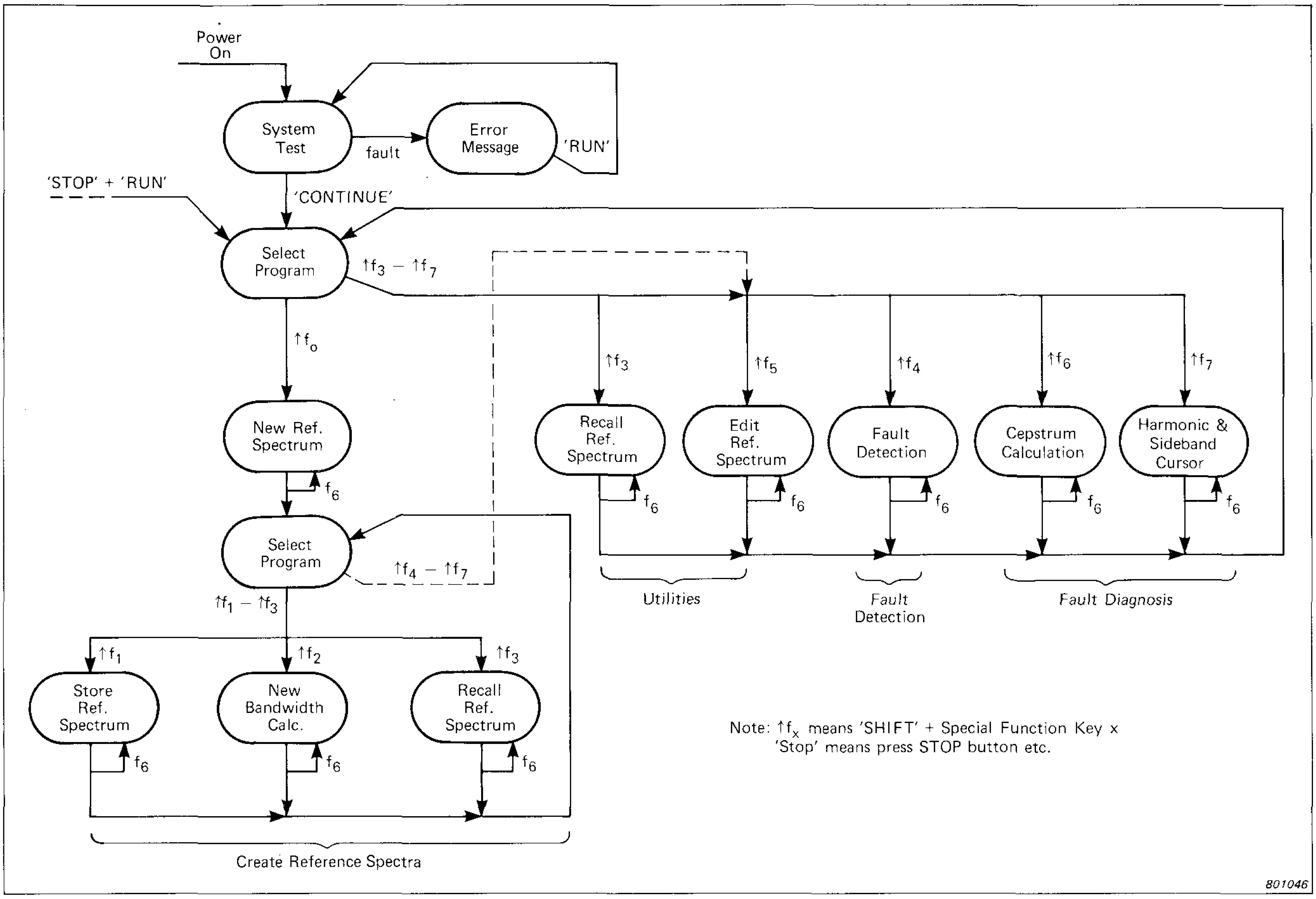


Fig.0.2. Selection of programs in BZ 0014

spectrum is created (and stored) of the machine when in good condition. This is done using programs 0 to 3 and possibly recalled and edited using program 5. A further machine spectrum would then be compared with the original using program 4 for detection of any possible faults. If any faults are found, these could be diagnosed using program 6 to create a cepstrum, and program 7 to detect the harmonics and sidebands. Fig.0.2 gives a more detailed view of program selection.

Fig.0.3 gives an example of a system used for the recording the vibration from a machine. The recording details i.e. preamplifier sensitivity, tape start and end point, etc. are noted down. Examples of a recording sheet, machine details, and machine layout are given on pages 3, 4 and 5 respectively. Blank copies of the forms are available on pages 20, 21 and 22.

The tape record length should be such that there is time for the averaging procedures in the program to operate. This can be determined from Table 1, where T_{min} is the absolute minimum averaging time in seconds. It is, however, recommended to record for longer than this to allow for operating the tape recorder and using the re-averaging keys 'f_0' and 'f_1' to recover from possible noisy sections of the tape.

The corresponding minimum length of tape required in metres is given by L_{min}.

Back in the laboratory, the data stored on the tape can be analyzed using the system shown in Fig.0.4.

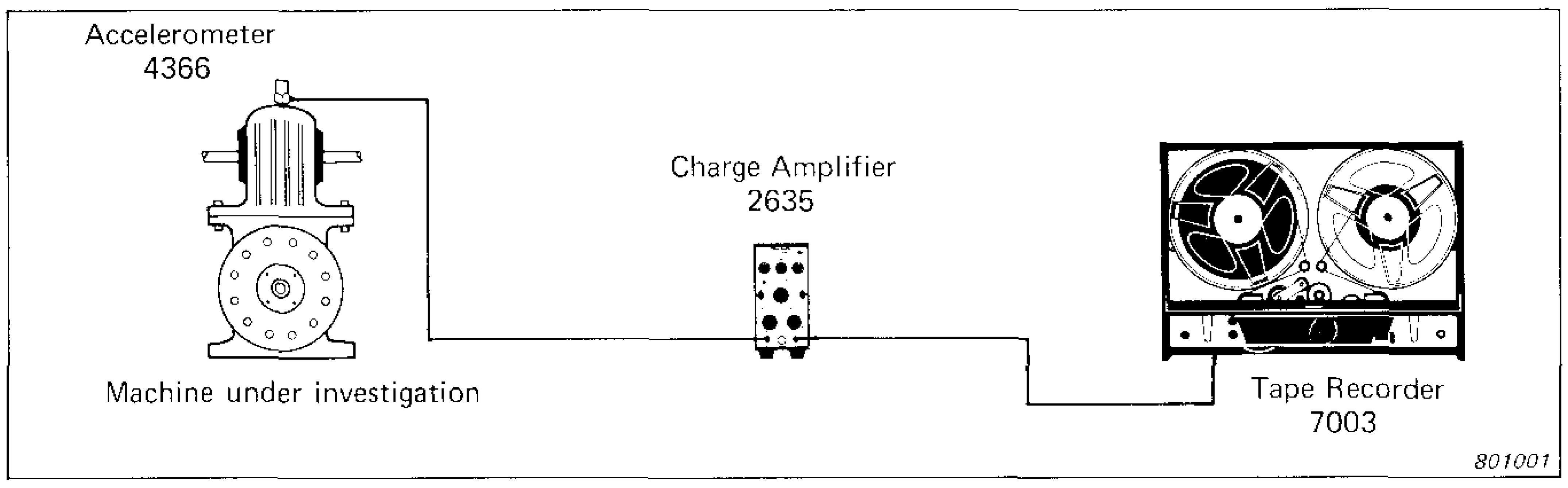


Fig.0.3. Recording Machine Vibration Data

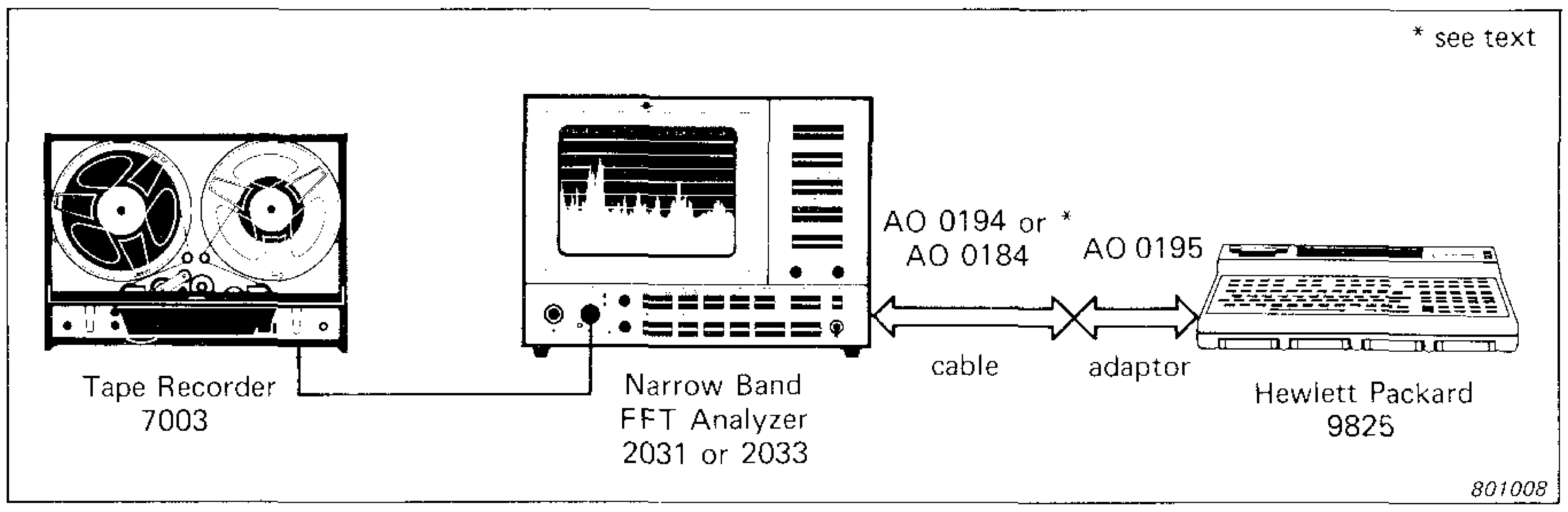


Fig.0.4. Analysis of Machine Vibration Data

RECORDING SHEET

Tape No. PC-1

Plant: Petrochem

Section: Ethylene

Date: 7/1-80

Tape Recorder: 7003

Accelerometer: 4369

Preamp: 2635

Machine No.	Meas. Pt.	Meas. Dir.	File No.	Reference Freq.	M.F.	Filters HP	Filters LP	Tape Speed	Ch.	Tape Counter stt.	Tape Counter fin.	Sensitivity V/Unit
Cal.									1	10	40	316 mV/10 mm/s
(14 mm/s									2	10	40	316 mV/10 mm/s
2 RI HP	1	H	101	120		10	10k	15	1	40	80	316 mV/10 mm/s
	1	A	102	120		10	10k	15	2	40	80	316 mV/10 mm/s
	2	H	103	120		10	10k	15	1	80	120	316 mV/10 mm/s
GB	3	H	104	120	x	10	10k	15	2	80	120	1 V/10 mm/s
	4	H	105	120	x	10	10k	15	1	120	160	316 mV/mm/s
	4	A	106	120	x	10	10k	15	2	120	160	316 mV/mm/s
	5	H	107	58,3	x	10	10k	15	1	160	200	316 mV/mm/s
	5	A	108	58,3	x	10	10k	15	2	160	200	1 V/10 mm/s
	6	H	109	58,3	x	10	10k	15	1	200	240	316 mV/mm/s
LP	7	H	110	58,3		10	10k	15	2	200	240	1 V/10 mm/s
	7	A	111	58,3		10	10k	15	1	240	280	316 mV/mm/s
	8	H	112	58,3		10	10k	15	2	240	280	316 mV/mm/s
TU	9	H	113	58,3		10	10k	15	1	280	320	316 mV/mm/s
	10	H	114	58,3		10	10k	15	2	280	320	316 mV/mm/s
	10	A	115	58,3		10	10k	15	1	320	360	316 mV/mm/s

Machine Speed: 3550 rpm

Load: 75%

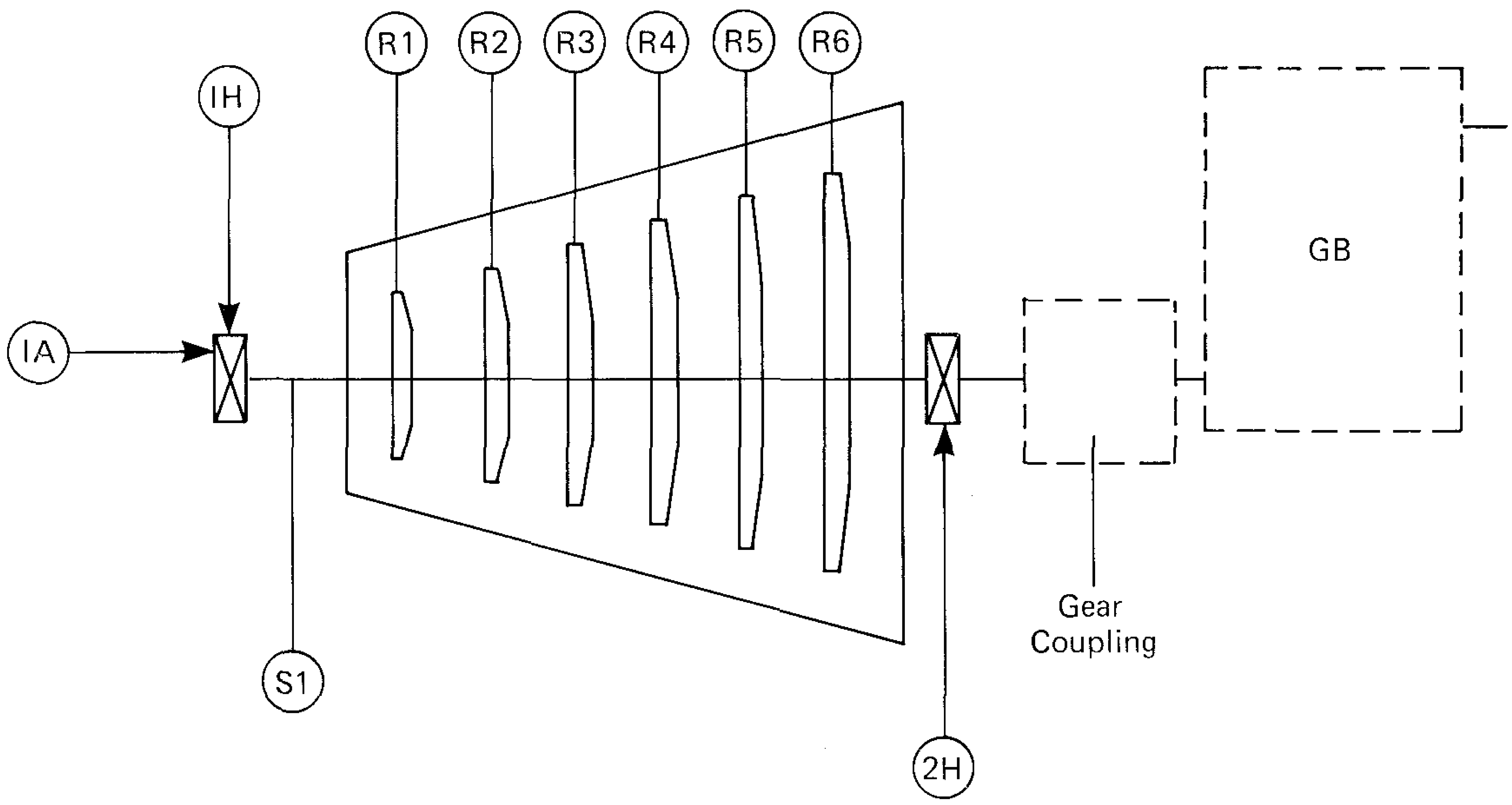
Remarks:

801137

MACHINE DETAILS

Plant: Petrochem **Section:** Ethylene **Date:** 5/1/80

Machine Nos.: 2 R1 HP (High pressure compressor)



Shaft No.	RPM	HZ	Gear No.	No. Teeth	Tooth mesh	Rotor No.	No. Blades	Blade-pass
S1	3500	58,3*				R1	23	1342
						R2	25	1458
						R3	25	1458
						R4	27	1575
						R5	27	1575
						R6	29	1692

Measurement Pt.	Bearing Type	*D*	*d*	*n*	ϕ	f_o	f_i	f_b	
1	J								
2	J								

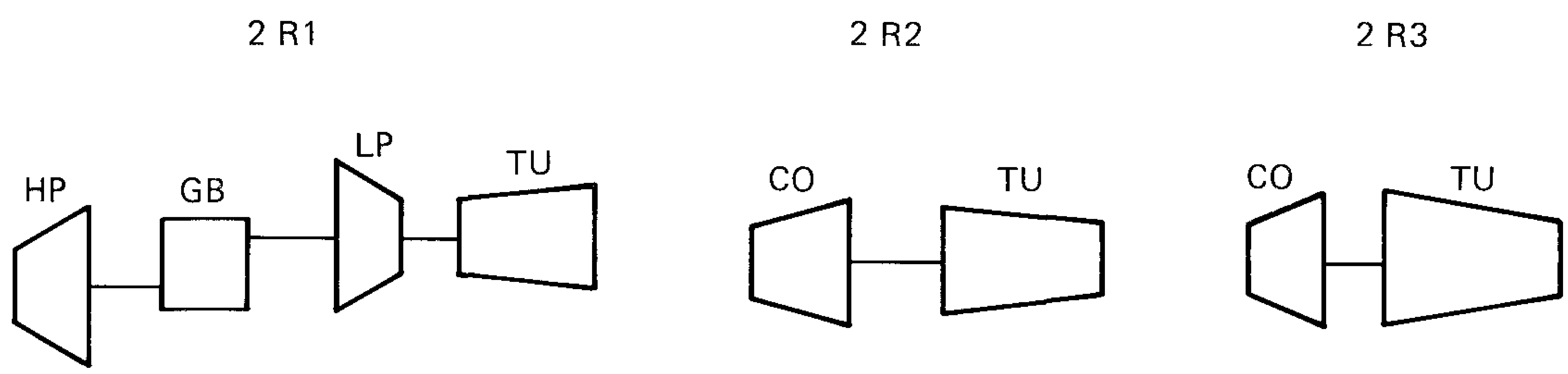
J = Journal brg. B = Ball brg. R = roller brg.

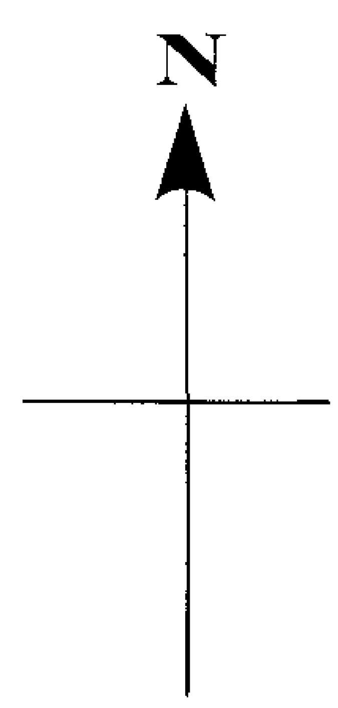
* Indicates Reference frequency

801139

MACHINE LAYOUT

Plant: Petrochem **Section:** Ethylene Platform **Date:** 5/1/80





Machine No.		File Nos.	Machine No.		File Nos.
2 R1	HP	101 – 103	2 R3	CO	131 – 133
	GB	104 – 109		TU	134 – 136
	LP	110 – 112			
	TU	113 – 115			
2 R2	CO	121 – 123			
	TU	124 – 126			

801141

Number of spectra averaged	T_{min} (seconds) / L_{min} (metres) — Full scale frequency: 20 kHz	10 kHz	5 kHz	2 kHz	1 kHz
4	13,6 / 5,2	22 / 8,4	40 / 15	93 / 35	182 / 69
8	23 / 8,8	41 / 16	76 / 29	182 / 69	359 / 137
16	42 / 16,0	78 / 30	148 / 56	359 / 137	714 / 272
32	81 / 31	151 / 58	292 / 111	714 / 272	1425 / –
64	158 / 60	298 / 114	580 / 221	1425 / –	2850 / –

800693

Table 1.0. Minimum Recording Times and Tape Length Required at a Tape Speed of 15 ips

Connection of Instruments

Connection between later Analyzers fitted with an IEC (625-1) male interface connector and the calculator is via B & K cable number AO 0194, and IEC/IEEE adaptor (B & K number AO 0195). For earlier Analyzers fitted with the B & K standard female slide-lock connector, use B & K cable AO 0184 and adaptor AO 0195. If there is doubt as to the type of connector fitted to the Analyzer, consult the instrument instruction manual.

Program Notes

In most cases it will be necessary to press 'CONTINUE' (shortened to 'CONT' on the calculator display) in order to move to the next instruction, this can be confirmed by referring to the relevant flow chart.

Most lower case symbols are replaced by capitals in both the calculator and Analyzer i.e. the symbol for decibels, dB, is replaced by DB. This is due to a restriction in the Analyzer text line and therefore used throughout for the sake of uniformity.

The programs can only operate on the Analyzer memory contents when the front panel switch settings coincide with the settings when the data was stored in the memory (these normally being set up by the program).

In order to terminate a particular program, press the calculator keys 'STOP' then 'RUN'. The calculator display will then read:

SELECT PROGRAM SHIFT f0, f3—f7

At this point, another program in the package can be accessed.

Operation

An overlay is supplied with the BZ 0014 program. This is placed over the calculator keys marked 'f0' to 'f9' to help to identify their function.

With the units connected together and switched ON, the program cartridge is loaded into the calculator. By then switching the calculator OFF then ON again the program is automatically read into the calculator.

Note: When the calculator is switched ON to run the program, a system reset signal is sent to the 2031/2033, which clears the data from the stores and memory. The program should therefore be loaded before the analysis of current data on the 2031/2033.

The first part of the program is a test program which is read automatically. Part of this program checks which Signal Analyzer is used i.e. the Type 2031 or 2033, and automatically selects the correct program. The test program also goes through a sequence checking that the instruments are functioning correctly. A list of possible displayed error messages with corrective action is given in the ERROR MESSAGES section. In order to interpret the hard copy error message, consult the calculator handbook. Part of this test sequence is a calibration check. Only if re-calibration is necessary, the 100 dB calibration signal will appear on the screen with the cursor centred on the reference signal. The calculator display will then read:

CHECK CALIBRATION THEN 'CONT'

If desired, the Analyzer can be recalibrated by adjusting the SENSITIVITY potentiometer beside the relevant INPUT until the textline level reads 100 dB. The calculator key 'CONTINUE' should then be pressed to advance to the next instruction. The calculator display will then read:

PROGRAM LIST?
Y(es)/'CONT'

To get a hard copy read-out from the calculator of the programs available press 'y' (or 'Y') then 'CONTINUE', if no program list is required, press 'CONTINUE'.

The display will then read:

SELECT PROGRAM
SHIFT f0, f3—f7

To access a program, the 'SHIFT' key is held down while an 'f' number key is pressed corresponding to the program number.

List of Programs Available

0) NEW REFERENCE SPECTRUM ('SHIFT' + 'f0')

1) STORE REFERENCE SPECTRUM ('SHIFT' + 'f1')

2) NEW PERCENTAGE BANDWIDTH CALCULATION ('SHIFT' + 'f2')

3) RECALL REFERENCE SPECTRUM ('SHIFT' + 'f3')

4) FAULT DETECTION PROGRAM ('SHIFT' + 'f4')

5) EDIT PARAMETERS PROGRAM ('SHIFT' + 'f5')

6) CEPSTRUM PROGRAM ('SHIFT' + 'f6')

7) HARMONIC AND SIDEBAND CURSOR PROGRAM ('SHIFT' + 'f7')

Special Function Keys

f0: RE-AVERAGE ONE DECADE

This key can be used during the averaging routines in program 0 and program 4 when the constant percentage bandwidth spectrum is being produced. The spectrum is formed by three sets of averages, one for each decade. If a faulty spectrum is observed on the analyzer screen during an averaging routine, caused perhaps by noise on the tape, this key can be pressed which re-starts the averaging in that particular decade.

f1: RE-AVERAGE ALL DECADES

This key can be used during averaging as with key 'f0', the function is the same as 'f0' except that the whole averaging routine is re-started from the beginning of the first decade. This might be necessary where the operator fails to press 'f0' in time when a faulty spectrum is observed and the averaging has started in the next decade.

f6: SPECIAL CONTINUE I

This key is used in some of the programs to provide a convenient opportunity to re-run the same program without getting a further print-out of the program heading.

f7: SPECIAL CONTINUE II

This key is used in some programs to enable further calculations to be performed within the same program after an initial calculation.

f8: HP DISPLAY UPDATE

When an instruction is displayed on the calculator, but it is desired to make a few calculations before continuing with the program, the instruction will be cleared from the display when the figures are entered via the calculator keyboard. On completion of the calculations, the original text may be recalled by again pressing 'f8'.

f9: HARD COPY OF PARAMETERS

If this key is pressed after a spectrum has been updated, a print-out of the parameters of the spectrum displayed on the analyzer is obtained from the calculator. The print-out consists of the full scale frequency, the reference frequency, the number of frequency bands in the spectrum, the number of spectra averaged per decade, the full-scale level in dB, the reference value to which the signal dB level is referred, the spectrum dynamic range and the tolerance in dB which gives the allowable increase in the frequency band before a fault is detected in program 4. The print-out gives a value for constant tolerance or the maximum and minimum values for dynamic tolerance.

f10: HARD COPY OF DATA

If this key is pressed after a spectrum has been updated, a print-out is obtained from the calculator. The relevant program description explains the contents of the print-out.

f11: TEXT TOGGLE

When a calculation has been made, the result is displayed on the text line at the top of the screen of the 2031/2033. To display the original text line, showing the control settings etc., press 'f11'. Pressing 'f11' a further time will re-display the results, and so on. Note that this key will only function on programs 6 and 7.

Program Description

0) NEW REFERENCE SPECTRUM

With a source of machine vibration data applied to the Analyzer input e.g. from a tape recorder, this program produces a constant percentage bandwidth (log freq.) spectrum with a full scale frequency within the range 1 kHz to 20 kHz. It is formed from averages on three adjacent decades of narrow band spectra. The signal can be conditioned to be in units of velocity or acceleration and a reference frequency chosen to enable compensation for machine speed changes when comparing with subsequent spectra in the Fault Detection Program 4.

The circled letters refer to the instruction on the flow chart Fig.0.4.

Ⓐ *The number of frequency* bands per decade is entered via the calculator keyboard which sets the channel bandwidth in the spectrum. This number should be a minimum of 10 and a maximum of 60. The relationship between the percentage bandwidth, the number of channels per octave and the number of channels per decade can be seen in Table 2. If no number is entered at this point, the program assumes *10 frequency* bands per decade which corresponds to a third octave spectrum.

Ⓑ This instruction asks whether the signal has units of acceleration or velocity. Displacement is not used as it has a limited frequency response and might not detect higher frequency components. If acceleration or velocity is used, the dB level will be referred to 10^{-6} m/s^2 or 10^{-5} mm/s respectively. If the signal source is not an accelerometer but e.g. a voltage source, 'CONTINUE' alone is pressed which enters the signal unconditioned into the Analyzer, the dB level being referred to 10^{-6} V.

Ⓒ If acceleration was chosen, the preamplifier sensitivity is entered the units being Volts per metres per second squared. This value should be found from the *Recording Sheet, having* been noted at the time the signal was recorded.

Ⓓ If velocity was chosen, the preamplifier sensitivity is entered the units being Volts per millimetres per second. This value should be found from the Recording Sheet, having been noted at the time the signal was recorded.

Ⓔ The Analyzer controls are set up, being mainly concerned with the F.S.FREQUENCY, INPUT ATT. 0 — 100 dB, and NO. OF SPECTRA *as the calculator* presets the other controls when performing the calculations.

Ⓕ After setting up the Analyzer and continuing, the calculator might indicate that the frequency is too low. This is because the setting of the F.S. FREQUENCY is below 1 kHz, the

Percentage	Channels/ Octave	Channels/ Decade
23,1	3	10
11,5	6	20
7,7	9	30
5,8	12	40
4,6	15	50
3,9	18	60

800697

Table 2.0. Relationship between Frequency Band Parameters

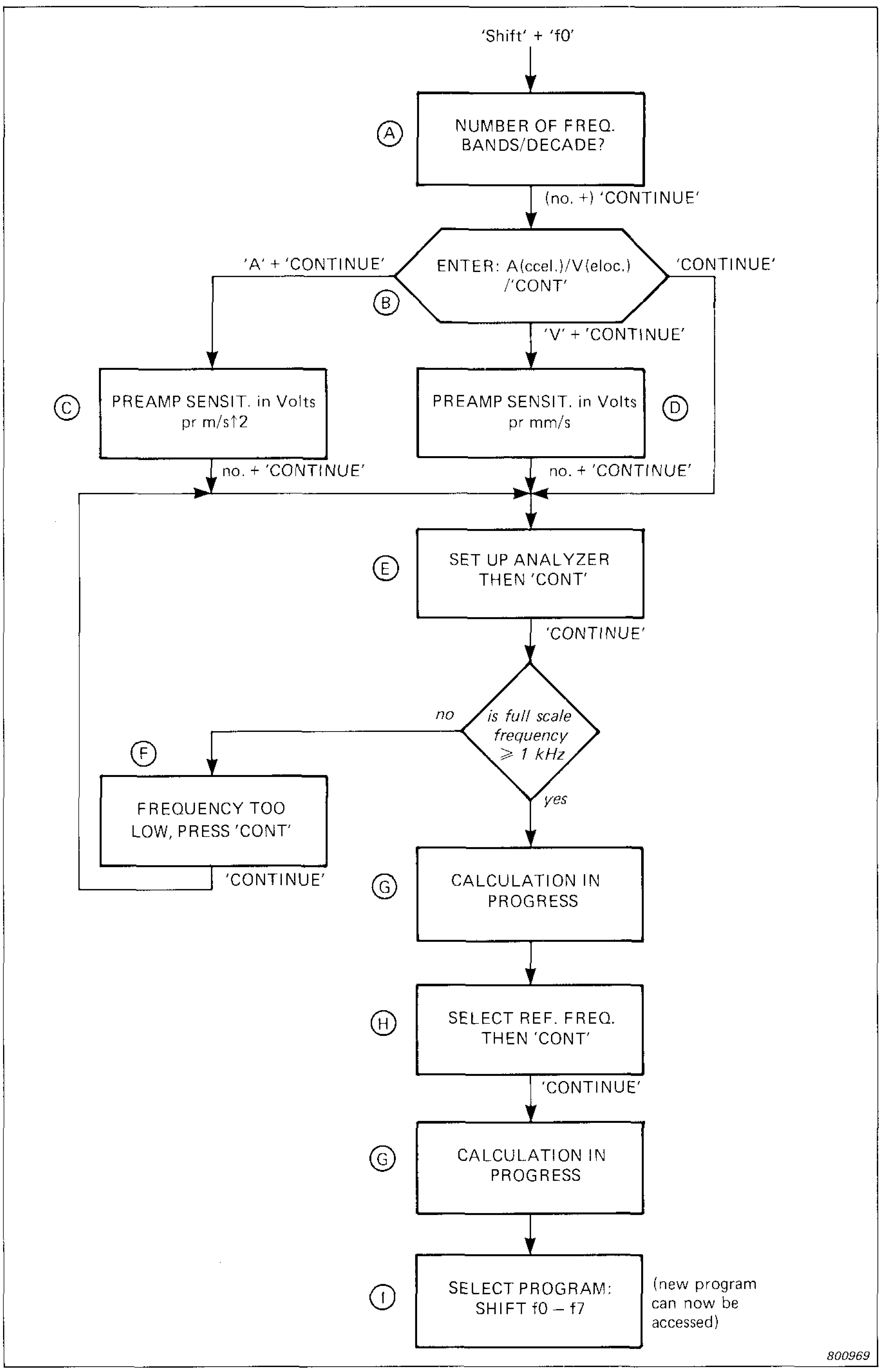


Fig.0.6. Flow Chart for NEW REFERENCE SPECTRUM Program

minimum full scale frequency for the averaging operations to be performed.

(G) This will be indicated when the calculator is producing the reference spectrum. The calculation could take a few minutes if the F.S. FREQUENCY is low and the NO. OF SPECTRA is high. During averaging the only Analyzer control which may be used is the AVERAGING STOP which may be used to cut short the averaging operations in that particular decade.

(H) A reference frequency is chosen so that any speed change in the machine can be compensated for in the Fault Detection program 4, as this speed change results in a shift in the logarithmic frequency spectrum. A high peak corresponding to one of the shaft speeds would be best as a reference as this could easily be identified in future spectra of the same machine. The frequency is chosen in the lowest decade which is displayed on the Analyzer when the instruction appears.

(I) The reference spectrum will appear in the averaging buffer and be displayed on the Analyzer screen. Another program in the package can now be selected.

If 'f10' is then pressed in order to get a hard copy of the data, the print out will give 'I' for input, as the spectrum is produced in the input averaging buffer, followed by the frequency and level at the cursor position. If 'f9' is pressed, the print-out will indicate 'I spectrum' followed by the parameters of the spectrum just produced. There will be no indication of the tolerance or dynamic range as this is chosen when the spectrum is stored using program 1. The screen text will show the full scale level in dB, the spectrum range in Hz, the number of spectra selected for averaging in each decade, and the frequency and level at the cursor position. Note that the dB value will be referred to 10^{-5} mm/s if velocity is chosen 10^{-6} m/s^2 if acceleration is chosen, otherwise it will be referred to 10^{-6} V if neither is chosen.

If a new spectrum bandwidth is then desired, program 2 can be selected. In order to visually compare this new spectrum with one stored on tape, program 3 can be selected. Otherwise program 1 can be selected to store the reference spectrum on tape.

1) STORE REFERENCE SPECTRUM

After a reference spectrum has been produced from program 0 it will be necessary to store the spectrum on tape for comparison with subsequent machine spectra. Before storing, the reference spectrum could be converted to a new percentage bandwidth using program 2, or visually compared with a spectrum recalled from the program tape using program 3. The tolerance (which gives the allowable limits of increase in levels of subsequent machine spectra produced using program 4) is inserted at this stage. The reference spectrum could if desired be recalled and edited using program 5.

The circled letters refer to the instruction on the flow chart Fig.1.0.

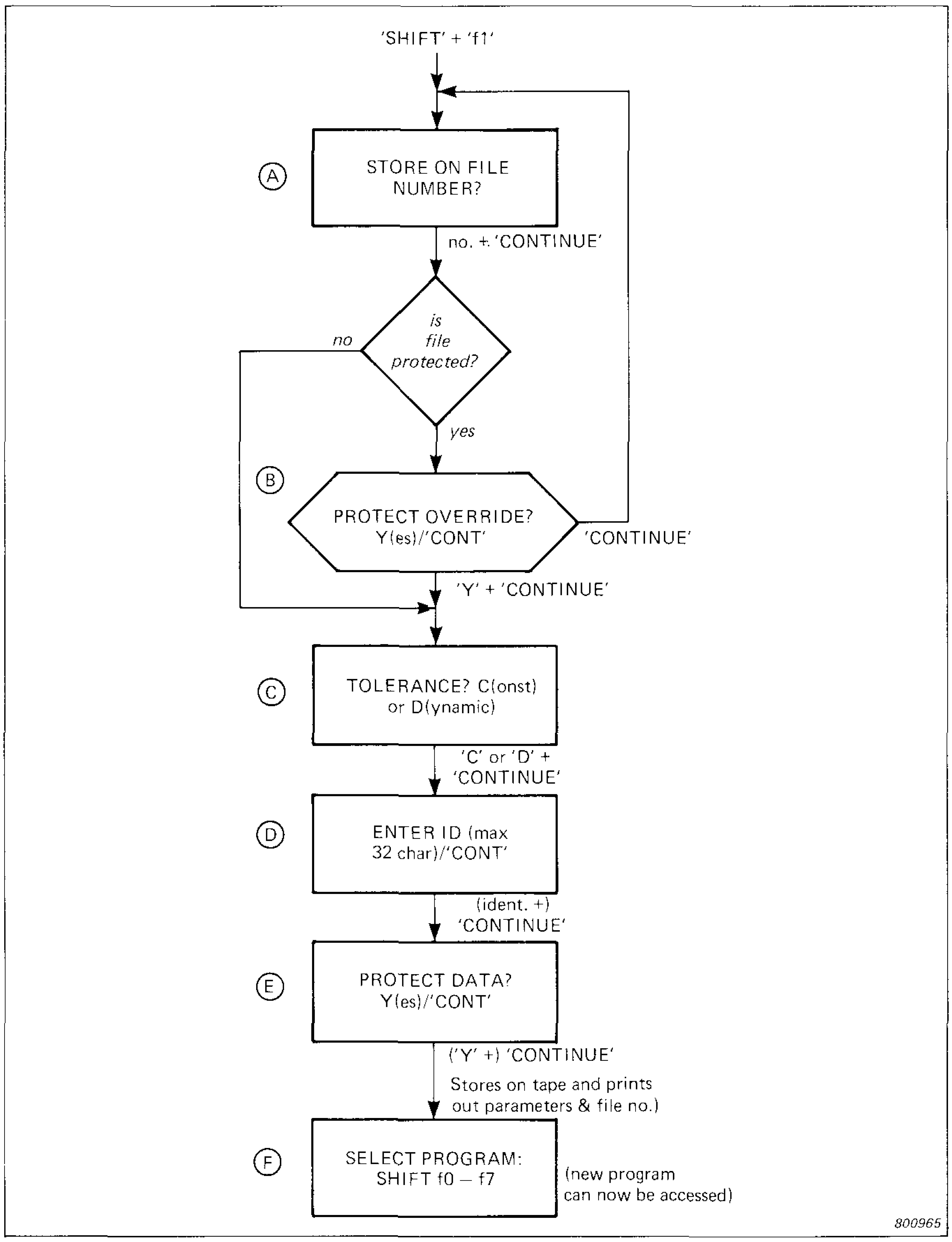


Fig.1.0. Flow Chart for STORE REFERENCE SPECTRUM Program

(A) The file number on which the reference spectrum is to be stored should be entered on the calculator keyboard. It is possible to store 320 reference spectra on the program tape.

(B) If the chosen file is protected *i.e.* the PROTECT DATA option was chosen when data was stored in the file, this instruction will appear. The choice can then be made of overriding the protection or storing the spectrum on another file number.

(C) The choice of tolerance is then given, being either 'constant' or 'dynamic'. The tolerance in dB gives the allowable increase in level in each frequency band (see Fig.4.1). If frequency bands in subsequent spectra increase by an amount greater than the chosen tolerance, a fault condition will be detected in the Fault Detection program 4. With constant tolerance, the same tolerance is assumed over the whole of the dynamic range of the spectrum. The default value will be 6 dB unless changed by the Edit program 5. With dynamic tolerance, the default values are 10 dB at the lower spectrum dynamic range limit and 4 dB at the maximum level, with a linear change in tolerance between these limits. This results in a de-sensitising of the lower signal levels, which may vary more because of noise. If desired, the two parameters could be changed by selecting the Edit program 5. Note that the default value of 'dynamic range' assumed is 40 dB, but this can also be modified using the Edit program 5.

(D) An identification is inserted which should be limited to 32 characters. This could be the measurement point number, the date, and machine load.

(E) The data to be stored on the tape can be protected from accidental erasure. If the file is protected, a protection override option is given when the user tries to store a spectrum on the file.

(F) The spectrum and parameters are stored on tape with an automatic print-out from the calculator of the file number and spectrum parameters. Another program in the package can now be selected.

If desired, a new percentage bandwidth could be produced using program 2 and re-stored using this program. Note that the new reference spectrum can only be stored on tape if the user keeps within programs 0 to 3 (see Fig.0.2).

2) NEW PERCENTAGE BANDWIDTH CALCULATION

With this program it is possible for the user to change the bandwidth of a logarithmic reference spectrum just produced using program 0 and placed in the input averaging buffer.

The circled letters refer to the instruction on the flow chart Fig.2.0.

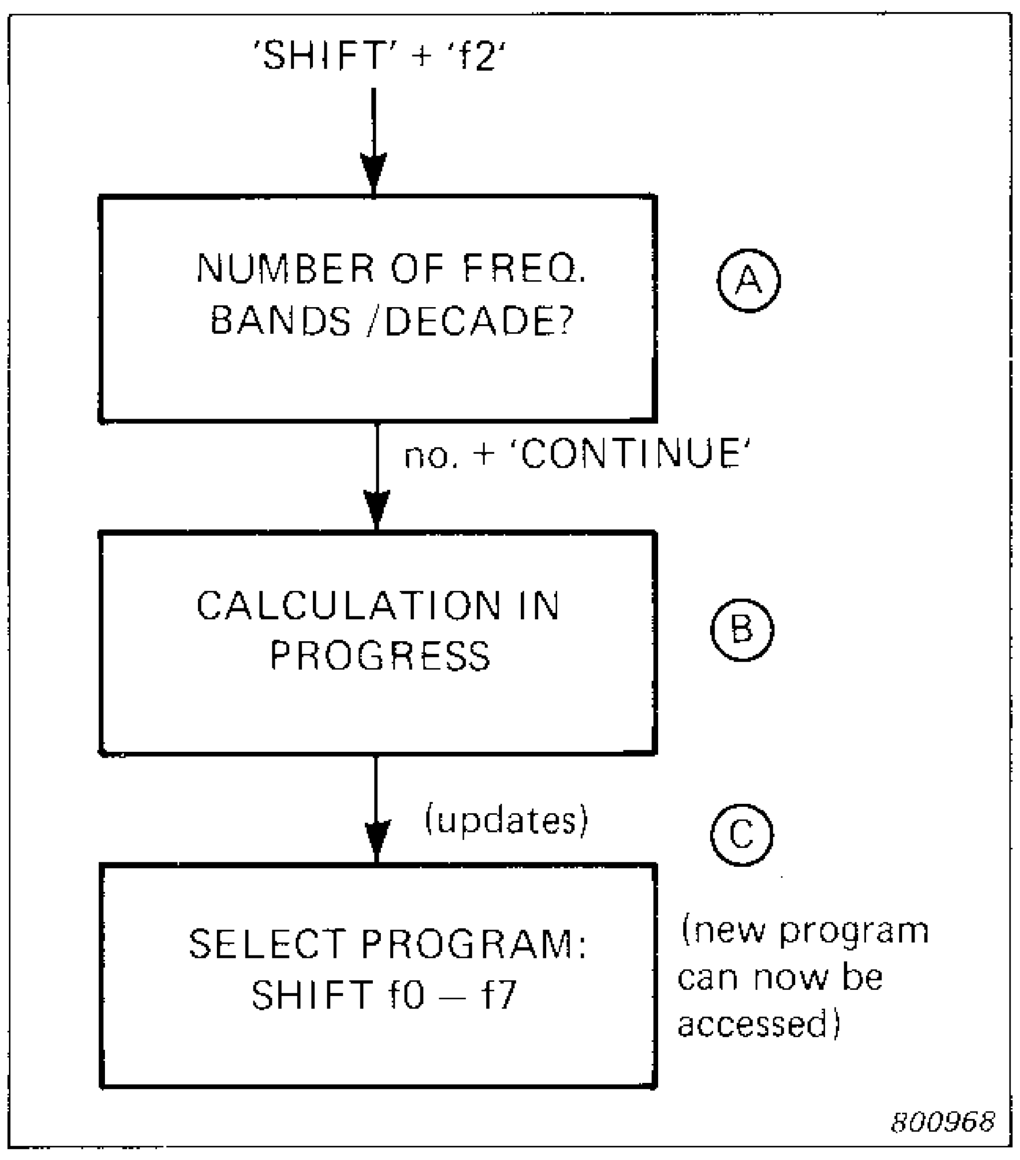


Fig.2.0. Flow Chart for NEW PERCENTAGE BANDWIDTH Program

(A) The number of frequency bands per decade is entered via the calculator keyboard which sets the channel bandwidth in the spectrum. This number should be a minimum of 10 and a maximum of 60. The relationship between the percentage bandwidth, the number of channels per octave and the number of channels per decade can be seen in Table 2. If no number is entered at this point, the program assumes 10 frequency bands per decade which corresponds *to a third* octave spectrum.

(B) This will be indicated when the calculator is producing the reference spectrum. The calculation could take a few minutes if the number of frequency bands entered is high.

(C) The new percentage bandwidth spectrum will be placed in the input averaging buffer and displayed on the Analyzer. Another program in the package can now be selected.

If 'f10' is then pressed in order to get a hard copy of the data, the print-out will give the frequency and level at the cursor position. If 'f9' is pressed, the print-out will give the parameters of the spectrum just produced. There will be no indication of the tolerance or dynamic range as this is chosen when the spectrum is stored using program 1. The screen text will show the full scale level in dB, the spectrum range in Hz, the number of spectra selected for averaging in each decade, and the cursor position frequency and level.

The new percentage bandwidth spectrum can then be compared with a recalled spectrum from the program tape using program 3. Otherwise program 1 can be selected to store the reference spectrum on tape. Note that program 2 only operates on a new reference spectrum just produced from program 0 if the user keeps within programs 0 to 3 (see Fig.0.2).

3) RECALL REFERENCE SPECTRUM

This program enables a reference spectrum to be recalled from the program tape. This could be used to compare a reference spectrum on the tape with one produced by using program

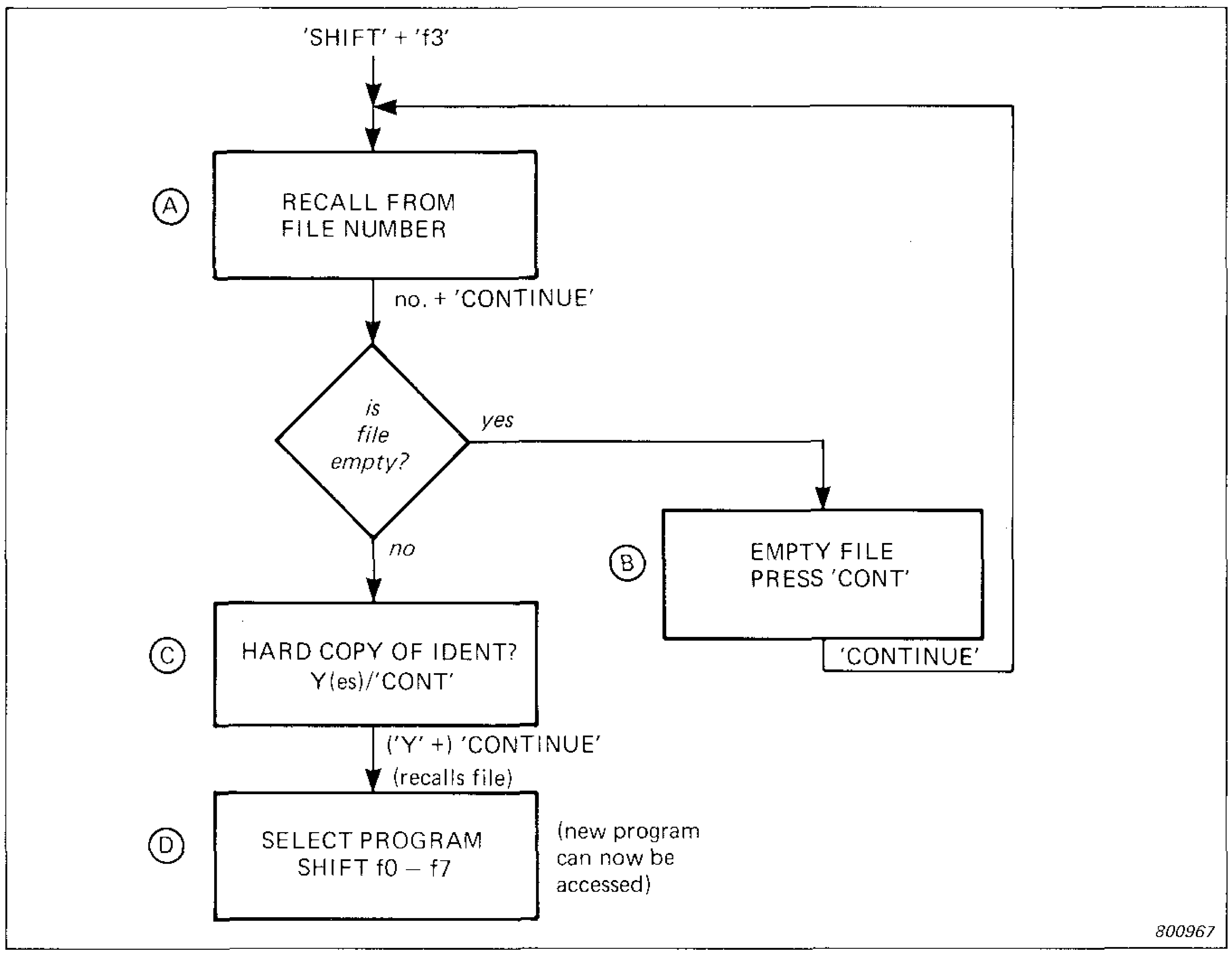


Fig.3.0. Flow Chart for RECALL REFERENCE SPECTRUM Program

0. Also a recalled spectrum can have its parameters analyzed to see if they need editing using program 5.

The circled letters refer to the instruction on the flow chart Fig.3.0.

Ⓐ The file number on which the reference spectrum is stored, should be entered on the calculator keyboard.

Ⓑ If the chosen file does not contain data, this instruction will result. By pressing 'CONTINUE', another file number can be selected.

Ⓒ A hard copy of the spectrum file number and data identification can be obtained from the calculator.

Ⓓ The spectrum is recalled into the memory buffer and displayed on the Analyzer screen. Another program in the package can now be selected.

4) FAULT DETECTION PROGRAM

This program compares a new spectrum created from an input signal (usually the output of a tape recorder) with a mask produced from a reference spectrum previously stored on the program tape. Changes in the speed of the machine are compensated for and the results of the comparison appear as a print-out from the calculator. Some examples of print-outs of comparison results can be seen in Fig.4.0.

The circled letters refer to the instruction on the flow chart Fig.4.2.

Ⓐ The file number on which the reference spectrum is to be stored should be entered on the calculator keyboard.

Ⓑ If the chosen file does not contain data, this instruction will result. By pressing 'CONTINUE', another file number can be selected.

Ⓒ The reference spectrum is recalled into the memory buffer. A new spectrum recording identification, which should be limited to 32 characters, is inserted via the calculator keyboard. This could be the date and machine load conditions.

Ⓓ This instruction will appear only if velocity was chosen for the reference spectrum. The preamplifier sensitivity is entered, the units being Volts per millimetres per second. This value should be found from the Recording Sheet, having been noted at the time the signal was recorded.

Ⓔ This instruction will appear only if acceleration was chosen for the reference spectrum. The preamplifier sensitivity is then entered, the units being Volts per

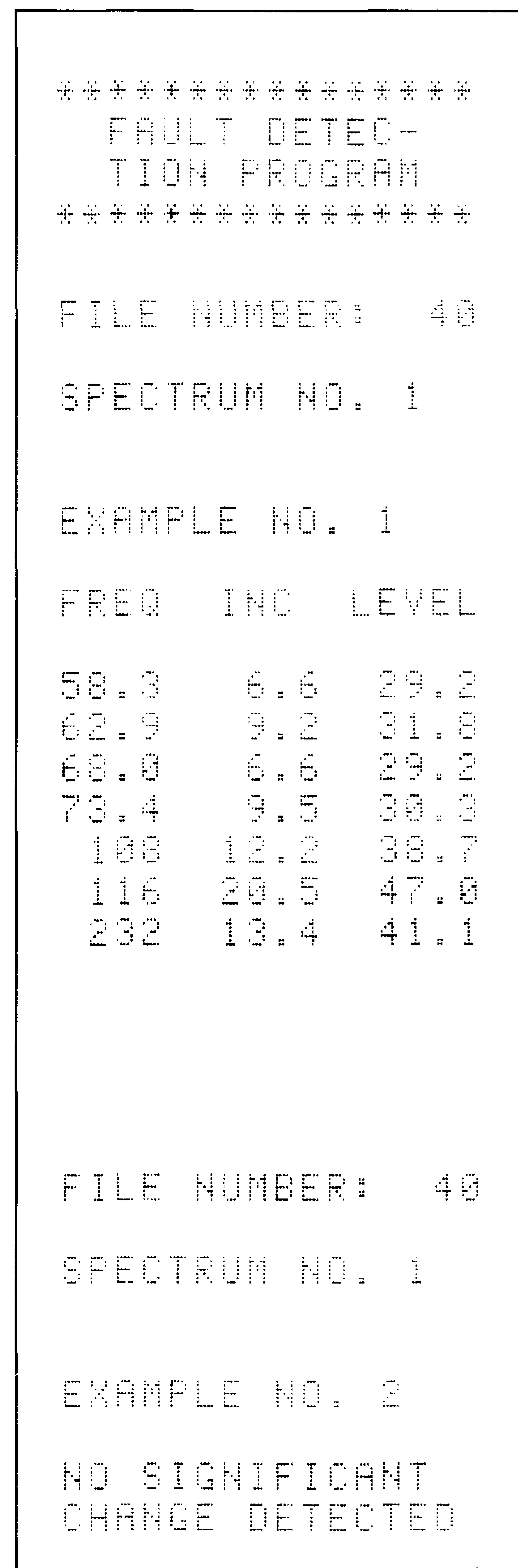


Fig.4.0. Examples of print-outs of comparison results

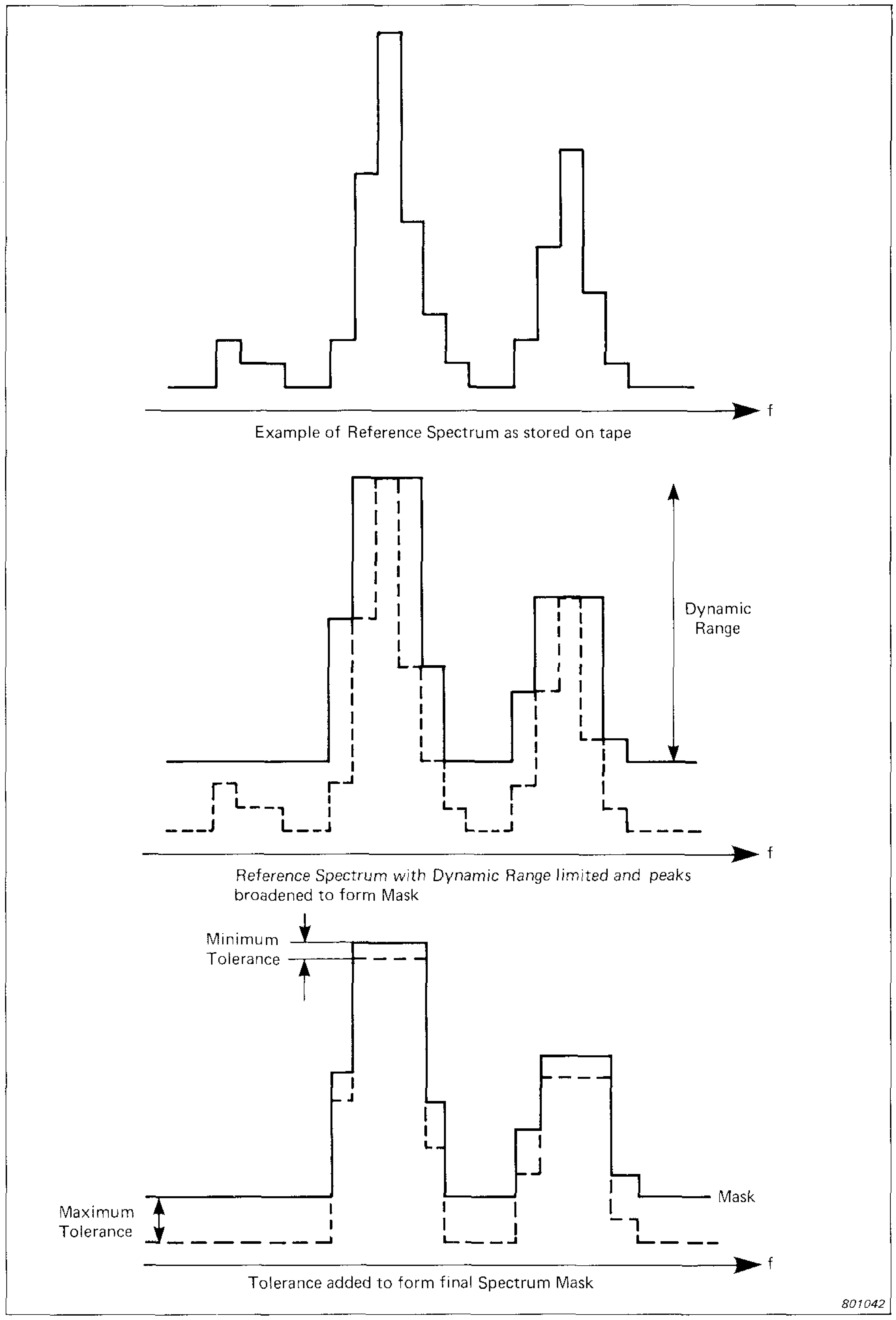


Fig.4.1. Formation of Mask from Reference Spectrum

metres per second squared. This value should be found from the Recording Sheet, having been noted at the time the signal was recorded.

(F) In most cases to apply the input signal will mean starting the tape recorder and adjusting the Analyzer input attenuator to avoid overload.

(G) This will be indicated when the calculator is producing the constant bandwidth spectrum from the new signal and comparing this spectrum with the reference spectrum. During averaging the only Analyzer control which may be used is the AVERAGING STOP which may be used to cut short the averaging operatings on that particular decade. The calculation could take a few minutes if the F.S. FREQUENCY setting on the Analyzer is low and the NO. OF SPECTRA is high.

(H) The lowest decade of the three narrow band spectra used in averaging will be displayed on the Analyzer screen with the cursor placed at the reference frequency selected in the reference spectrum. The cursor should then be placed at the same peak as in the reference spectrum, which might not coincide in frequency because of a speed change in the machine. The new spectrum will then be compensated for variation in machine speed. If compensation is necessary, this will be shown on a print-out from the calculator.

(I) A constant percentage bandwidth spectrum will then be created from the input signal and compared with a mask formed from the reference spectrum (see Fig.4.1). The results of the comparison will appear as a print-out from the calculator.

The newly produced spectrum will be in the input buffer and displayed on the Analyzer screen after the calculations are completed. If the MEMORY function is then pressed, this will show the spectrum mask without the tolerance added (See Fig.4.2.). The Analyzer controls SLOW or FAST ALTERNATE or I/M can be used for further comparison between the new and reference spectra. Note that with alternating spectra, the Analyzer textline will display the I-spectrum text.

The reference spectrum parameters can then be edited at this point using program 5. For further analysis of the machine signal, the Cepstrum program 6 and the Harmonic and Sideband program 7 can be selected to analyze a constant bandwidth spectrum in the appropriate frequency range.

Fig.4.1 shows the formation of a spectrum mask. The spectrum envelope is formed to allow for any small remaining differences of less than one bandwidth in the spectrum caused by machine speed changes. The limited 'dy-

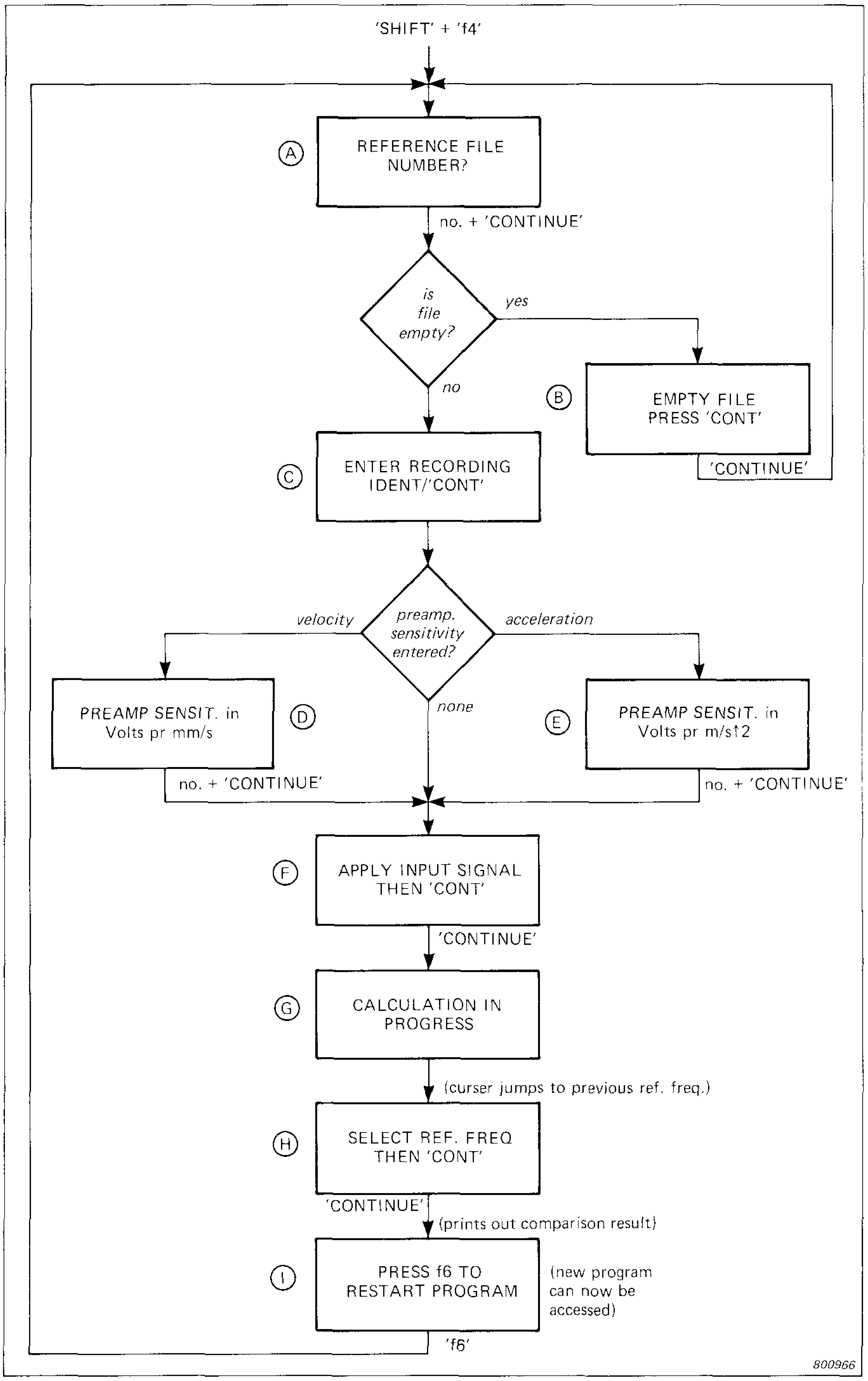


Fig.4.2. Flow Chart for FAULT DETECTION Program

namic range' is to minimise the effect of low level noise which could otherwise lead to an erroneous fault condition. The default value of 'dynamic range' assumed is 40 dB, but this can be modified using the Edit program 5. The tolerance, being either 'constant' or 'dynamic', gives the allowable increase in level in each frequency band. With constant tolerance, the same tolerance is assumed over the whole of the dynamic range of the spectrum. This default value will be 6 dB unless changed by the Edit program 5. With dynamic tolerance, the default values are 10 dB at the lower spectrum dynamic range limit and 4 dB at the maximum level, with a linear change in tolerance between these limits. This also decreases the influence of the lower spectrum levels on the comparison results. If desired, the two parameters could also be changed by selecting the Edit program 5.

5) EDIT PARAMETERS PROGRAM

The parameters of a spectrum stored on the program tape can be changed using this program. This could be used to optimise the comparison of spectra of a particular machine when using the fault detection program 4. Also parameter errors, made when producing the reference spectrum, could be rectified. A list of spectrum parameters can be found from the description of Special Function Key f9 on page 7.

The circled letters refer to the instruction on the flow chart Fig.5.0.

(A) The file number of the reference spectrum to be edited should be entered on the calculator keyboard.

(B) If the chosen file does not contain data, this instruction will result. By pressing 'CONTINUE', another file number can be selected.

(C) A hard copy of the reference spectrum parameters could be obtained from the calculator. This hard copy will be headed RECALL FILE to distinguish the parameters from those of the edited version. A list of spectrum parameters can be found in the description of special function key f9 on page 7.

(D) The choice of changing the data identification is then given which could indicate that the spectrum has been edited.

(E) This instruction will only appear if the user chose to change the data identification. The new identification, which should be limited to 32 characters, is then entered via the calculator keyboard.

(F) If a new number of spectra is required when averaging to produce the reference spectrum, it should be entered on the calculator keyboard at this stage. This number should be between 1 and 2048 in a binary sequence e.g. 1, 2, 4, 8, etc. Note that if a higher number of spectra is chosen, the averaging procedures will take longer, therefore a longer record length will be required. The minimum recording time can be determined from Table 1, where T_{min} is the absolute minimum averaging time in seconds. It is, however, recommended to record for longer than this to allow for operating the tape recorder and using the re-averaging keys 'f0' and 'f1' to recover from possible noisy sections of the tape. The corresponding minimum length of tape required in metres is given by L_{min}.

(G) This instruction will appear only if velocity was chosen for the reference spectrum. If it is desired to edit the preamplifier

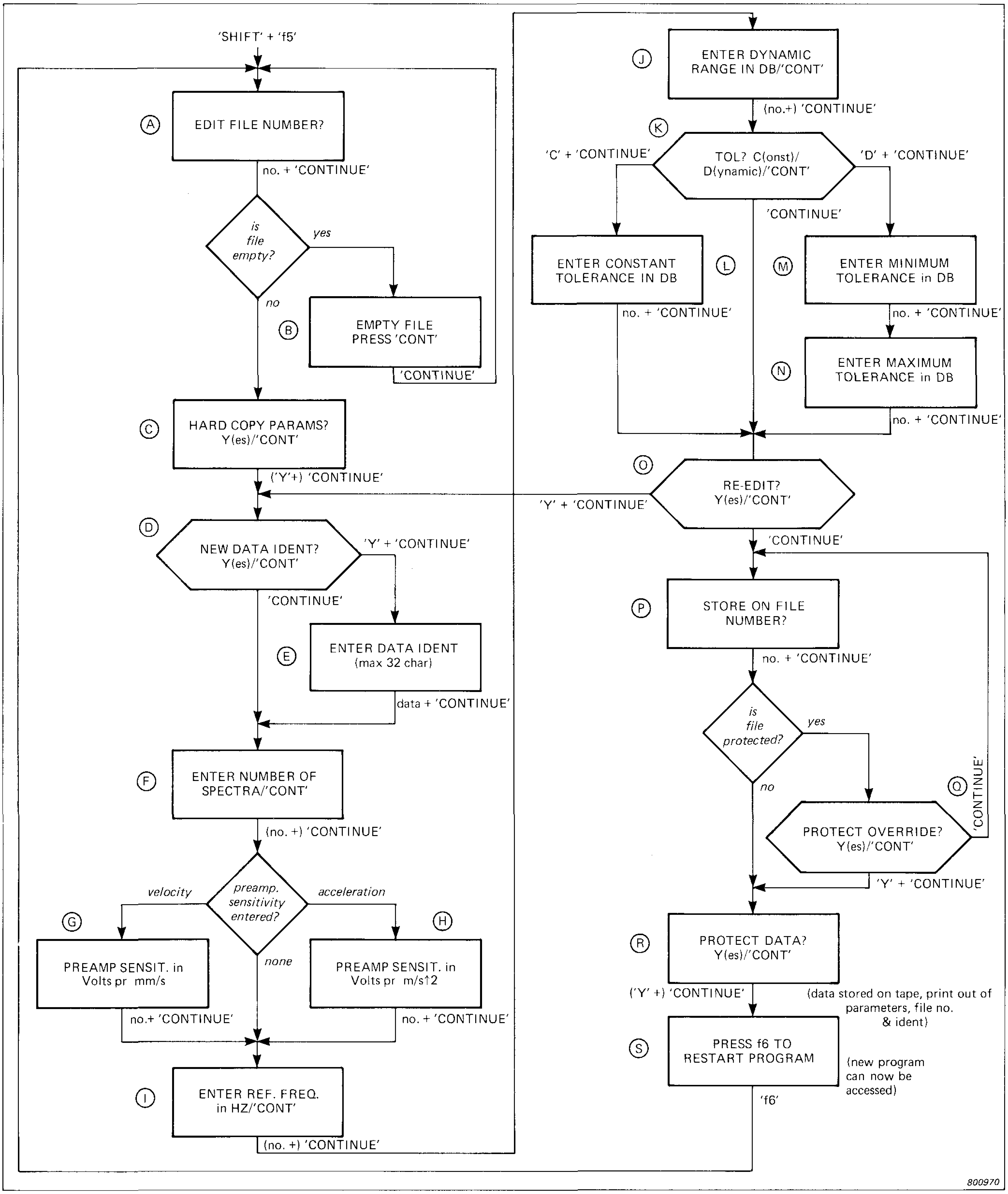


Fig.5.0. Flow Chart for EDIT PARAMETERS Program

sensitivity, the new value is entered via the calculator keyboard, the units being Volts per millimetres per second. This value should be found from the Recording Sheet, having been noted at the time the signal was recorded.

(H) This instruction will appear only if acceleration was chosen for the reference spectrum. If it is desired to edit the preamplifier sensitivity, the new value is then entered via the calculator keyboard, the units being Volts per metres per second squared. This value should be found from the Recording Sheet, having been noted at the time the signal was recorded.

(I) If the reference frequency, chosen when creating the reference spectrum from program 0, proves difficult to locate on subsequent machine spectra, a new frequency value can be entered at this stage via the calculator keyboard.

(J) The dynamic range of a spectrum is the difference between the level of the highest peak and the lowest level to be considered (see Fig.4.1). This is set at 40 dB when a reference spectrum is created from program 0 but can then be changed by entering a new value via the calculator keyboard. This might be useful if there is a lot of noise at low signal levels, if there is some lost information due to the limited dynamic range or for low noise signals.

(K) If the tolerance value is to be edited, the choice of tolerance is then made, being either 'constant' or 'dynamic'. The tolerance in dB gives the allowable increase in level in each frequency band (see Fig.4.1). With constant tolerance, the same tolerance is assumed over the whole of the dynamic range of the spectrum. This default value is set at 6 dB when the reference spectrum is created using program 0. With dynamic tolerance, the default values are 10 dB at the lower spectrum dynamic range limit and 4 dB at the maximum level, with a linear change in tolerance between these limits. This results in the lower levels, which may vary more because of noise, having a lesser influence. If frequency bands in subsequent spectra increase by an amount greater than the chosen tolerance, a fault condition would be diagnosed in the Fault Detection program 4.

(L) Only if 'constant' tolerance was chosen this instruction will result. The new value of tolerance is then entered via the calculator keyboard.

(M) Only if 'dynamic' tolerance was chosen this instruction will result. The new value of minimum tolerance is then entered via the calculator keyboard.

(N) This instruction will also only result if 'dynamic' tolerance was chosen. The new value of maximum tolerance is then entered via the calculator keyboard.

(O) This gives the opportunity of re-editing the parameters if e.g. a mistake was made when editing. If this option is taken, the re-editing will be performed on the edited parameters not on the original.

(P) The file number on which the edited spectrum is to be stored should be entered on the calculator keyboard. It is possible to store 320 reference spectra on the program tape.

(Q) If the chosen file is protected i.e. the PROTECT DATA option was chosen when data was stored in the file, this instruction will appear. The choice can then be made of overriding the protection or storing the spectrum on another file number.

(R) The data to be stored on the tape can be protected from accidental erasure. If the file is protected, a protection override option is given when the user tries to store a spectrum on the file.

(S) The spectrum and edited parameters are stored on tape with an automatic print-out from the calculator of the file number, identification code and spectrum parameters. Another program in the package can now be selected. The print-out of the edited parameters will be headed STORED FILE to distinguish it from those of the spectrum recalled from the program tape.

If key 'f10' on the calculator is then pressed, a print-out will result of all the lines of the spectrum with their frequency and level.

6) CEPSTRUM PROGRAM

The cepstrum is a useful diagnostic technique as it locates periodic components in a machine vibration spectrum which could otherwise be difficult to see. These components could be harmonics or sidebands whose spacing might identify the source. With this program a cepstrum can be calculated from a constant bandwidth spectrum displayed on the Analyzer screen. The spectrum can be edited to erase unwanted information and the cepstrum can be re-scaled to amplify low level components.

The circled letters refer to the instruction on the flow chart Fig.6.0.

(A) A constant bandwidth spectrum is produced using the Analyzer and displayed on the screen. The spectrum can be in either the inst. buffer, the averaging buffer or the memory. However, if a spectrum is in the inst. buffer, it will be destroyed when the cepstrum calculation takes place. This can be remedied by transferring the spectrum to the averaging buffer. To achieve this, first ensure that the Analyzer AVERAGING controls are on STOP and LIN. and the NO. OF SPECTRA as at 1. By then pressing AVERAGING START, the input spectrum will be copied in the averaging buffer. Note that with the 2031, the averaging controls should be set before the spectrum is recorded.

(B) The option of spectrum editing is then given. This can be used to selectively erase parts of a spectrum to see which parts of

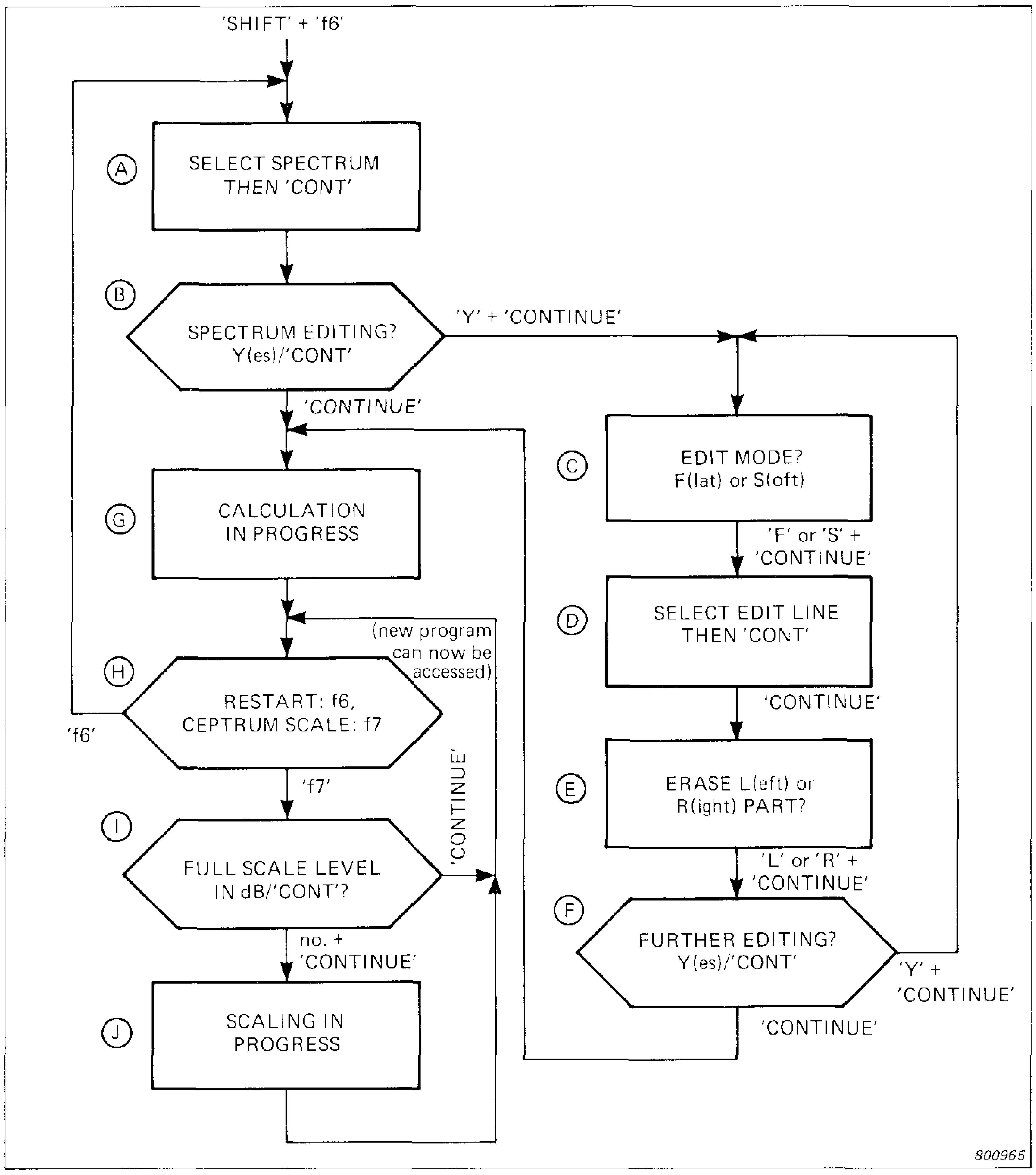


Fig.6.0. Flow Chart for CEPSTRUM Program

the spectrum contain particular modulation components.

The instructions (C) *to* (F) will result only if spectrum editing is chosen.

(C) A choice is made of either 'flat' or 'soft' mode. With the 'flat' mode, the edited spectrum maintains the same level as that at the cursor position. With the 'soft' mode, there is a linear tapering of the spectrum over 50 lines from the cursor position, thereafter the edited spectrum maintains the level at the cursor position.

(D) The cursor on the Analyzer is moved to the edit line.

(E) The choice of erasing the left or right side of the prechosen edit line is made.

(F) Further editing may then be done e.g. to erase the right portion of the spectrum after having erased a left portion. Further soft editing in the same position as before, creates a roll-off proportional to exponential N, where N is the number of times edited. The edited spectrum appears in the memory buffer and is displayed on the screen.

(G) This will be indicated when the calculator is producing the cepstrum.

(H) The cepstrum is placed in the time function buffer and appears on the analyzer display screen. When the cepstrum is produced, it is in the 390 line mode. As there are 512 lines in the cepstrum, the remaining lines can be observed by using the TIME FUNCTION MOVE control. The spectrum can be rescaled by pressing 'f7' and inserting the full scale level in dB, or the program can be restarted by pressing 'f6', otherwise another program in the package can be selected.

(I) Having pressed 'f7' to rescale the cepstrum, the new peak to peak level is entered via the calculator keyboard.

(J) This is displayed for a short time while the cepstrum is being rescaled.

(H) The rescaled cepstrum appears on the screen.

The Analyzer text line shows the peak to peak level in dB, calibrated such that if a cosine wave was displayed over the 400 lines of the spectrum, the corresponding line in the cepstrum would give the peak to peak level shown in the cepstrum textline. The Type 2033 also reminds the operator to multiply the quefrency by 10 if a cepstrum is made from a spectrum in zoom. If 'f11' is then pressed to toggle the text, followed by pressing 'f10' to get a hard copy of data, a print-out will be produced from the calculator of the cursor position line number and quefrency. The quefrency can also be read from the Analyzer text line.

Having found the spacing of the frequency components, program 7 could be selected to help to locate all the harmonics and sidebands with their levels.

7) HARMONIC AND SIDEBAND CURSOR

With a given constant bandwidth spectrum, in either the input, averaged or memory buffer, this program enables the harmonics and sidebands to be located with their frequency and level. Note that when analyzing a spectrum in the memory buffer, the Analyzer front panel switch settings should coincide with those when the data was stored. However, if the cepstrum program 6 has previously been selected, the spectrum will probably be found in the input averaged buffer.

The circled letters refer to the instruction on the flow chart Fig.7.0. Ⓐ to Ⓔ refer to the harmonic section of the program and Ⓕ to Ⓛ refer to the sideband section.

Ⓐ The user makes the choice of selecting the harmonic section of this program.

Ⓑ A frequency spectrum is selected and displayed on the screen.

Ⓒ Either the cursor is placed on the fundamental frequency which results in the frequency value being calculated, or the estimated frequency value is inserted via the calculator keyboard.

Ⓓ If the fundamental frequency is not well defined, centred in the first two lines of the spectrum, or over line 200 such that the second harmonic is off the screen, this instruction will result. Another attempt at choosing the first harmonic will then be possible.

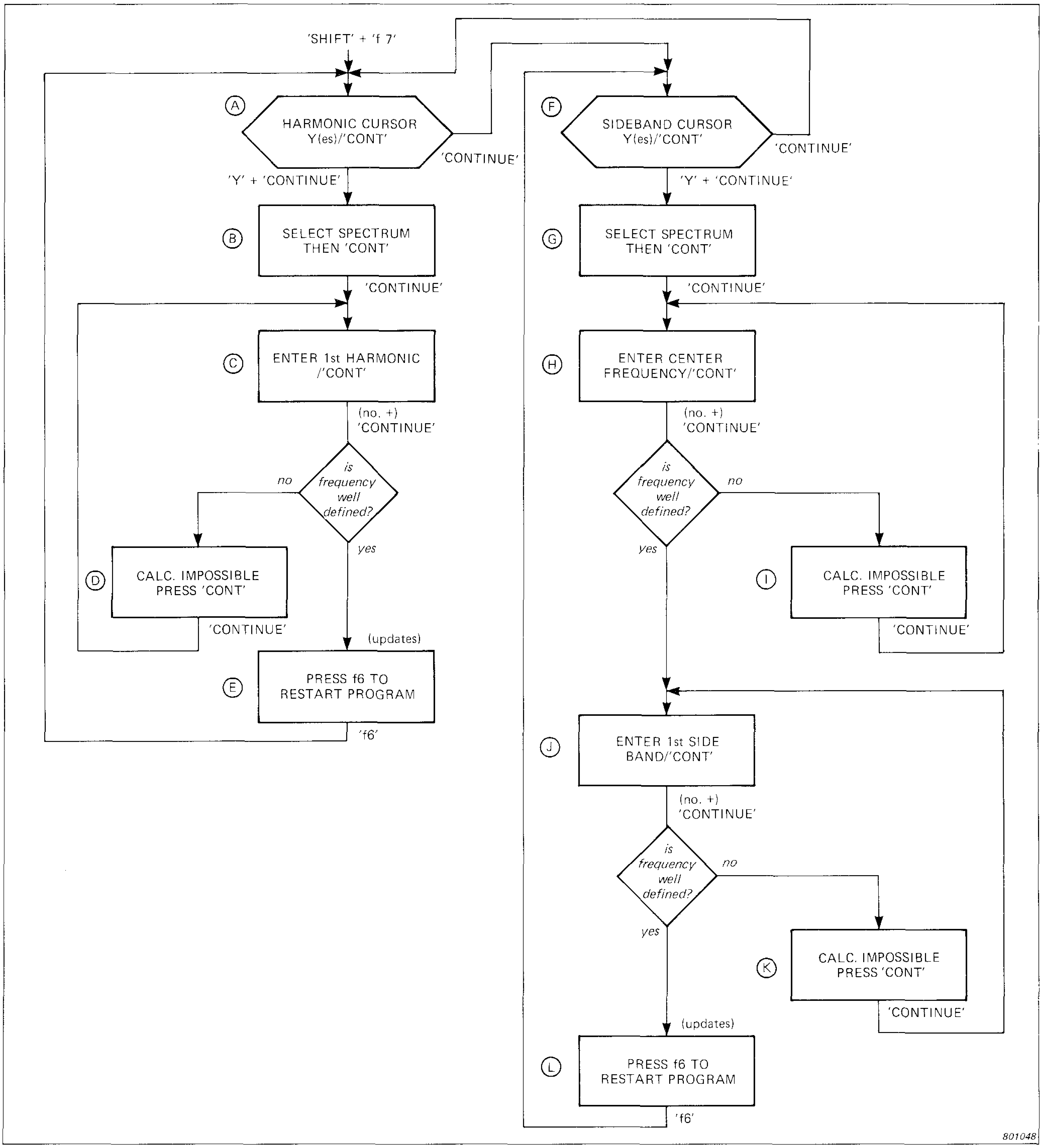


Fig.7.0. Flow Chart for HARMONIC AND SIDEBAND CURSOR Program

(E) The calculation is performed and the cursor moves to the appropriate line in the spectrum nearest to the centre frequency of the fundamental. By pressing the calculator keys marked ← or →, the cursor will jump to the higher order harmonics, giving a read-out of the frequency obtained with each harmonic. If the cursor is then moved to a high order harmonic with these same keys, it might be seen that the cursor does not coincide exactly with the centre frequency of the harmonic. By first ensuring the cursor is on the flank of the correct peak, pressing 'f7' will update the centre frequencies of all the harmonics including the fundamental to a more accurate value.

The screen text and the hard copy read-out give the number of the harmonic as well as its frequency. The key 'f11' could then be used to toggle the text with the original in order to find the level of the harmonics relative to the first harmonic e.g. 1st harmonic level = 0 dB.

The program can be restarted by pressing 'f6' which also enables the sideband cursor program, otherwise another program in the package can be selected.

(F) The user can choose the sideband section of the program.

(G) A frequency spectrum is selected and displayed on the screen.

(H) Either the cursor is placed on the centre frequency which results in the frequency value being calculated, or the estimated frequency value is inserted via the calculator keyboard.

(I) If the centre frequency is not well defined or centred in the first or last two lines of the spectrum, this instruction will result. Another attempt at choosing the centre frequency will then be possible.

(J) Either the cursor is placed on the first sideband, left or right, which results in the frequency value being calculated, or the estimated frequency value is inserted via the calculator keyboard.

(K) If the sideband is not well defined, or centred in the first or last two lines of the spectrum, this instruction will result. Another attempt at choosing the first sideband will then be possible.

(L) After the calculation, the centre frequency value and the values of all the sidebands in the chosen spectrum are displayed when the cursor is moved, again by pressing the calculator keys marked <— or —>. As with the Harmonic Cursor, the frequencies can be updated if desired by selecting high order sidebands and pressing 'f7'. Note that this only updates the sideband spacing not the centre frequency value.

The screen text and the hard copy read-out indicate which band (centre, right side or left side), the sideband number (if a sideband is indicated), and the centre frequency of the band. The key 'f11' could then be used to toggle the text with the original in order to find the level of the sidebands relative to the centre frequency e.g. centre frequency level = 0 dB.

ERROR MESSAGES

This section explains what error messages might appear on the calculator display during the running of a program and the action required to clear the error. There are some error messages where it may prove necessary to re-run the program through the calculator after clearing the error. If this procedure is adopted, it should be noted that switching on the calculator to re-run the program sends a system reset which clears the analyzer of all data on the screen and in the memory.

Test Program

When the tape is first inserted and the BZ 0014 program run, a test program is sequenced, checking whether the system is operating correctly. Possible error messages at this stage are as follows:

INSUFFICIENT MEMORY

MISSING STRING ROM

MISSING ADVANCED PRG. ROM

MISSING GENERAL I/O ROM

These four instructions are concerned with the plug-in modules on the calculator, if any of the modules are missing then the relevant error message will appear on the display

If there is no extended input/output ROM, then the program will not run. The instrument must then be switched OFF, the correct modules fitted, and the program run by switching the unit ON again.

WRONG SELECT CODE ON HP-IB

On the back of the calculator there is a plug-in interface (No. 98034) with a select code setting, adjustable with a slotted screwdriver. If this is not reading number 7 (the correct code for these units), then the above error message will result. The instrument must then be switched OFF and the correct code set with a screwdriver. When the unit is switched ON, the program will be automatically re-run in the calculator.

ANALYZER DOWN OR HP-IB ERROR

This error message will appear if the frequency analyzer is not functioning or if there is a fault in the interface between the instrument. Check also with the relevant instruction manual that the correct address code is set on the switches on the back panel of the Analyzer. If there is no obvious fault, the instruments should be switched OFF and separated from each other to check them manually. By then re-connecting the instruments and switching ON, the program is re-run. If the system still proves faulty, the instruments should be switched OFF before consulting your local B & K service representative.

Main Program

If no faults are found in the test program, the first instruction will appear on the calculator display. This signifies the start of the main program.

When the main program is running, the error messages which could result are as follows:

PRINTER OUT OF PAPER

See the calculator handbook on how to replace the paper roll.

NO CARTRIDGE IN TAPE TRANSPORT

Replace cartridge into transport mechanism.

TAPE IS WRITE PROTECTED

The tape has a facility for protecting the stored information from accidental erasure. If the above message results, then remove the tape cartridge from the calculator. In one corner of the cartridge there is a section marked RECORD which should be slid in the direction of the arrow. The cartridge should then be re-inserted into the calculator.

TAPE OR TAPE TRANSPORT ERROR

This message appears when there is a problem with the reading of information on the tape. This could be caused by dirt on the tape heads or a faulty tape or tape transport mechanism. For further information on clearing this fault, consult the H.P. manual.

ANALYZER DOWN OR HP-IB ERROR

This error message will appear if the frequency Analyzer ceases to function, is incorrectly addressed or if a fault develops in the interface between the instruments. The correction procedure is laid out in the previous TEST PROGRAM section under the same error message.

PROGRAM EXECUTION ERROR

If an incorrect procedure is followed when performing calculations with the program, this error message may result. The error will usually be cleared by following the procedure laid out in the following paragraph, otherwise it may prove necessary to re-run the program. If this error message still continues to be displayed, then contact your local B & K service representative.

Continuation of Program (Main Program)

If the fault causing the error message in the main program is cleared, the word 'cont' should be typed on the keyboard followed by the error line number which can be seen from the hard copy print-out. The key 'EXECUTE' is then pressed which continues the program from the point where the error message occurred.

RECORDING SHEET

Tape No.

Plant: Section: Date:

Tape Recorder: Accelerometer: Preamp:

Machine No.	Meas. Pt.	Meas. Dir.	File No.	Reference Freq.	M.F.	Filters HP	Filters LP	Tape Speed	Ch.	Tape Counter stt.	Tape Counter fin.	Sensitivity V/Unit

Machine Speed: Load:

Remarks:

801138

MACHINE DETAILS

Plant: Section: Date:

Machine Nos.:

Shaft No.	RPM	HZ	Gear No.	No. Teeth	Tooth mesh	Rotor No.	No. Blades	Blade-pass

Measurement Pt.	Bearing Type	D	d	n	ϕ	f_o	f_i	f_b	

801140

MACHINE LAYOUT

Plant: Section: Date:

Machine No.	File Nos.	Machine No.	File Nos.

801142

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