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April 28, 1982

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Ms. E. G. Adensam, Chief
Licensing Branch No. 4
Model D Steam Generator Operation

Re: McGuire Nuclear Station, Unit 1
Docket No. 50-369

Dear Mr. Denton:

The original operation program for McGuire Nuclear Station Unit 1 following the March outage for steam generator inspection was transmitted to NRC by Duke Power Company in a March 16, 1982, letter to H. R. Denton. It was proposed at that time that McGuire 1 be operated for a time period of approximately 100 days of which no more than 60 days would be at power levels greater than 50% but less than or equal to 75%. In an NRC letter from R. L. Tedesco dated April 1, 1982, Duke was given permission to operate McGuire, Unit 1 for 1500 hours at 50% power. Specific concerns related to proposed operation at power levels higher than 50% were also stated in this letter. These concerns were in four major areas:

1. Uncertainty in the estimate of the maximum size of the existing wear defects in McGuire, including correlation of length to volume and calculational methods used to estimate defect volume.
2. Insufficient justification for using a defect volume of 1×10^{-3} cubic inches as the allowable defect volume.
3. Unavailability of vibration data from instrumentation installed inside steam generator tubes in the preheater area of McGuire 1.
4. Insufficient evidence that high tube wear rates do not occur at power levels between 50% and 75%.

The purpose of this submittal is to address concerns and to provide additional justification for a proposal for operation of McGuire 1 for a limited time at 75% power.

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The proposed short term operating program is as follows:

- Upon receipt of NRC concurrence, increase power to 75%
- Operate for a maximum of 720 hours at power levels between 50% and 75%
- Reduce power to 50%

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- Operate at 50% power until no later than July 4, 1982
- Perform eddy current testing (ECT) of first three rows of all steam generators

Operation after the ECT will depend upon the test results. Our ultimate objective is to demonstrate the feasibility of extended operation at 75% power and to operate at this power until a modification is installed. The proposed 30 days operation at 75% is the first step in this demonstration. It is anticipated that following the June/July ECT a longer operating period at 75% would be proposed assuming the ECT results show no significant additional wear. Details of this follow-on program would be developed after evaluation of the ECT results and discussed with NRC at that time.

Very truly yours,

William O. Parker, Jr.

William O. Parker, Jr. By, RMC

GAC/jfw

cc: Mr. P. R. Bemis
Senior Resident Inspector
McGuire Nuclear Station

Mr. James P. O'Reilly, Regional Administrator
U. S. Nuclear Regulatory Commission
Region II
101 Marietta Street, Suite 3100
Atlanta, Georgia 30303

McGuire Nuclear Station

Response to Robert L. Tedesco's Letter dated April 1, 1982

Estimate of the Maximum Defect Size

In the previous submittal dated March 16, 1982 the nature of four eddy current indications found in the C steam generator at McGuire 1 was described and justification was presented for the selection of 1.5×10^{-4} cubic inches as an upper bound for the volume of the largest defect. While we continue to believe that the largest defect is smaller than 1.5×10^{-4} cubic inches in volume, we agree with the NRC comment that this estimate cannot be adequately supported in a quantitative manner considering the limitations of eddy current measurement techniques to size defects of extremely small volume. We, therefore, have increased our estimate of the largest of the wear defects existing in McGuire 1 to 4.0×10^{-4} cubic inches for calculational purposes. The following justification of the use of this value is presented:

1. The axial extent of the largest defect in McGuire 1 was measured using absolute eddy current techniques and by using support plate subtraction. The approximate length is 0.375 inches. Considering possible error in measuring the defect size, an upper bound of 0.5 inches in axial extent may be established. A comparison of this axial length with that of defects on tubes removed from Almaraz and Ringhals shows that an axial extent of 0.5 inches is consistent with a defect volume of less than 4×10^{-4} cubic inches.

2. Measurement of eddy current signal amplitude - A comparison of the amplitude of the largest eddy current defect signal in McGuire 1 with the amplitude of a number of laboratory produced defect signals shows the amplitude of the field defect corresponds to the amplitude of a laboratory produced defect with a volume of approximately 4×10^{-4} cubic inches. Because the actual defect signal obtained in the field has a higher noise content than those obtained in the laboratory, we conclude that the amplitude method is conservative in predicting defect volumes.

Similar results were obtained when the amplitude of the McGuire defect signal was compared with amplitudes of defect signals from tubes removed from Ringhals, except that the estimate for the defect volume for the largest McGuire defect was less than 4×10^{-4} cubic inches.

3. Template matching - In our earlier submittal, we described the template matching method in which the size and shape of the distorted tube support plate signals in a steam generator are compared with the size and shape of distorted tube support plate signals from known defects. At that time, we estimated using this method that the volume of the largest defect in McGuire was approximately 8×10^{-4} cubic inches. It should be noted that the match was not very accurate due to the fact that the laboratory produced defects which we used for comparison were perfectly square geometrically, with no taper in the axial or circumferential directions, and longer than the measurement of the McGuire defect. Thus, template matching was, as expected, the most conservative method of approximating the volume of the defect in the McGuire steam generator. It is concluded that the measurement obtained from template matching is unrealistically conservative and that a better template match should be attempted if this method is to be used to estimate defect volume.

After weighing all of the results obtained in attempting to size the four defects noted in the eddy current inspection of steam generator C, it is concluded that the defect volumes are well below a size for which an accurate measure can be made. Our estimates of defect volume are, therefore, more likely to be estimates of the smallest defect for which a reasonable attempt may be made to establish a volume estimate rather than an actual estimate of volume of the existing defects. However, the volume which we have established as an upper bound, 4.0×10^{-4} cubic inches, has considerable quantitative support and can be therefore be used as a conservative estimate of the defect volume for McGuire. Our best estimate of the largest defect volume in McGuire continues to be less than 1.5×10^{-4} cubic inches.

Establishment of the Maximum Allowable Defect Size

In our previous submittal to NRC, we established a maximum allowable defect size of 1×10^{-3} cubic inches. We have reevaluated this limit and have reconfirmed our confidence that it represents a reasonable defect size to be used as an upper limit for additional allowable wear. This conclusion is supported by the following facts:

1. Figure 1 shows a plot of defect volume versus through wall penetration for the defects on six tubes removed from Ringhals and Almaray. Because of the wide range in defect volumes, it is necessary to use a logarithmic scale for a defect volume; defect depths are shown on a linear scale in units of mils (1 mil = .001 inches). Note that the defect depth associated with the leaking tube from Ringhals does not correspond to 100% through wall. Examinations of photomicrographs from sections of the failed tube indicate that wear had progressed approximately 85% through wall before the leak occurred. Use of 85% penetration (37 mils) is therefore more accurate than using 100% penetration for this wear defect. From this figure the following conclusions may be drawn:

   a. The defects naturally fall into two groups. The smaller defects (volumes less than 1×10^{-3} cubic inches, depths less than 10 mils) form the first group while the larger defects, of which six points are available including the defect at which the leak occurred, appear to form a different group. The grouping of the defects in this manner is most likely due to the "saturation" occurring in the defect geometry as the defect progress through wall -- that is, the axial extent and circumferential extent become, respectively, .75 inches and 180-200 degrees uniformly over the whole defect surface, and the defect taper is worn away such that the depth becomes more uniform. Thus, the maximum depth becomes more representative of the average depth for the larger defects, with a corresponding decrease in percent change in volume lost as a function of through wall penetration. This theory is supported qualitatively by the photographs of defects on the removed tubes. It is important to note that the volume and

depth of the largest defect is consistent with the volumes and depths of the other five large defects.

b. The allowable defect size of approximately 1 x 10^{-3} cubic inches for McGuire is smaller by a factor of 3.5 than the largest defect (in volume) for which through wall penetration was 10 mils (or 23% of tube wall). A typical deeper defect which has a penetration of 16 mils (or 37%, which puts it close to the McGuire plugging limit) has a volume of 6.5 x 10^{-3} cubic inches. It can be concluded that a defect with a volume approximately 1 x 10^{-3} cubic inches must grow substantially larger before it begins to approach the plugging limit.

c. Even though data from only six tubes are available, the tubes which were examined represent a variety of conditions. They are from two different units in different countries, there are large differences in operating history, tubes with support at every baffle location and those which pass through baffle windows are represented, and the six tubes represent six different tube locations across the face of the tube bundle. Some of the tubes are located directly at the edge of the impingement plate; others are located closer to the outer edges of the first row. Yet it can be seen from Figure 1, where the points from Ringhals tubes are marked with an "R" and those from Almaraz are marked with an "A", that there is significant agreement among all the defects in the relationship between defect volume and defect depth. Particularly around a defect size of 1 x 10^{-3} cubic inches, where there are ten points recorded, there is a consistent and predictable relationship between defect volume and depth, and we can establish an upper bound of defect depth for a volume of 1 x 10^{-3} cubic inches at 10 mils or 23% of tube wall. A defect of this depth would have no adverse impact on the long term reliable operation of the McGuire steam generators and could be easily detected and conservatively sized with the eddy current techniques which we have previously used at McGuire.

2. Eddy current examination of the Almaraz unit was performed in March 1982, following 1500 hours of operation at 50% power. Evaluation of the data from this inspection has shown that no measurable tube wear occurred during that operating period. At that time, a new method of sizing defects using eddy current signal amplitude was used to reexamine some of the larger defects from the original inspection, including defects in a tube that was plugged as a result of the inspection in November 1981. This new eddy current interpretation technique was developed in response to the inaccuracy of the original method where defect sizing resulted in errors of 200-300%. Even though Almaraz operated over 500 hours at 100% power, it now appears that the maximum defect in any tube is near or below the plugging limit. For one of the previously plugged tubes, where a defect greater than 60% had been measured using conventional eddy current techniques, the largest defect was actually 15% when sized using the refined eddy current method. This new eddy current method has been accepted by the Swedish regulatory authorities and was used as a basis to establish which tubes were required to be plugged at Ringhals 3 prior to returning to power. It is apparent from this reevaluation of the severity of the tube wear problem that operation of McGuire at 75% is very unlikely to result in high rates of wear. Therefore, we conclude that a maximum allowable defect volume of approximately 1×10^{-3} cubic inches, corresponding to a through wall depth of less than 25%, is a conservative upper bound which will not be exceeded by our proposed operating program.

McGuire Tube Vibration Measurement Program

In March 1982, accelerometers were installed in two tubes located in steam generator A at McGuire 1. These tubes are row 49-column 40 and row 49-column 71. Each tube received two biaxial accelerometers; therefore, eight channels of acceleration data were available. Figure 2 shows a plan view of these accelerometer locations and the orientations of the sensitive axes of the biaxial accelerometers. The lower accelerometer in each tube was located within the elevation of the second baffle plate, and the upper accelerometer was located in the midspan region of the preheater inlet pass. Figure 3 shows an elevation view of the accelerometer locations. The tube located at row 49-column 40 coincides in location with one of the four tubes that showed evidence

of wear in steam generator C; therefore, there is some reasonable assurance that at least one pair of accelerometers is located at the location of maximum vibratory excitation in the steam generator.

During plant operation following the installation of these accelerometers, power was increased to 75% in increments and data were recorded for the eight acceleration channels. This recording was done on magnetic tape, and the tapes were analyzed by conventional vibration analysis techniques. A digital storage oscilloscope was used to observe the unfiltered time signals. Frequency domain analysis, including power spectrum analysis for both acceleration and displacement, was used. By applying the x and y axis signals from the biaxial accelerometers to the x and y axes of the oscilloscope, orbital patterns of the acceleration response were observed. The resulting signals were compared with those obtained in experimental studies of heat exchanger tube vibration performed by several experimenters.

Figure 4 shows how to interpret the plots of vibration time histories. Typical unfiltered time histories of tube acceleration are shown in Figures 5 through 20 for power levels of 0, 20%, 50%, 65%, and 75%. As can be seen, there is a gradual increase in vibration activity as power level is increased. Quantitative evaluation of these unfiltered time histories cannot be performed because the accelerometer mount resonance at about 700 Hz and the accelerometer resonance itself at about 1500 Hz create a non-linear response characteristic. However, qualitative assessment reveals periods of low activity with turbulent bursts of greater activity occurring frequently. It can be concluded that the tubes are being buffeted by random bursts of turbulent fluid forces at all power levels, with increasing amplitude as power level is increased. Figures 21 through 30 illustrate time histories for some of the same power levels with a 250 Hz low pass filter used to eliminate the non-linear response range for the accelerometer and its mount. Responses in this range represent the lower natural frequency modal responses (the fundamental and perhaps the first three or four harmonics). These time histories also show that the tube responds in a random manner to the fluid forces with increasing amplitude as power level increases.

Figure 31 shows how to interpret the graphs of power spectral density. Figures 32 through 66 show power spectral densities for the acceleration response of the tubes. The power spectral density measures the power content of the tube vibration signal as a function of frequency, and therefore indicates at which frequencies the predominant tube response occurs. From Figure 52, which shows the power spectral density at 50% power for accelerometer 71TX (that is, the x axis for the top accelerometer in tube 49-71) it can be seen that the tube response is predominantly at a single frequency of about 40 Hz, with an amplitude at this frequency of 0.1 g^2. Figure 54 shows the corresponding power spectral density for 75% power for the same accelerometer. Note that the peak at about 40 Hz has increased to 0.12 g^2 and a peak at about three times this fundamental frequency, or about 120 Hz, has appeared with an amplitude of about 0.06 g^2. This particular accelerometer was selected for this comparison because it shows the maximum vibrational activity by a factor of two or more. Similar results can be seen for the other instrumented tubes.

By performing two time integrations of the accelerometer data, it is possible to obtain tube displacement as a function of time. Figures 67 through 72 show typical energy spectral densities (root mean square) for displacements. As can be seen from these graphs, there is very little tube vibratory displacement occurring at either the baffle plate location or at the midspan of the first preheater pass.

The following conclusions may be drawn from the analysis of steam generator tube vibration at McGuire:

1. There is no evidence of a threshold of fluidelastic instability at any of the monitored locations. The onset of fluidelastic instability is characterized by a sudden large increase in vibration amplitude at one predominant response frequency. The magnitude of this amplitude change can be as high as 100 times greater than the response below the threshold, and there is an unmistakable and dramatic change in the character of tube response above the onset of instability. As can be seen from the McGuire data, there are no sudden changes in tube response, either in the amplitude or the predominant frequencies of response above

50% power. It can be concluded that tube vibration, and therefore tube wear, does not increase in an unpredictable fashion as power level increases and that small increases in power will produce correspondingly small increases in tube wear.

2. The broadband random nature of the tube vibration can be associated with a random buffeting of the steam generator tubes by the fluid forces. In such turbulent excitation, the root mean square tube displacement is related to the mean flow velocity as

$$(\bar{X}^2 - X^2)^{1/2} = k\,\bar{U}^{3/2} \qquad \text{(Reference 1)}$$

where

X = tube displacement

$\bar{X}$ = mean tube displacement

K = proportionality constant

$\bar{U}$ = mean flow velocity in the gap between the tubes.

This equation is valid if the response is predominantly at the fundamental frequency and the scale of turbulence does not change. It can be concluded that the vibration response of the tubes in the McGuire steam generator can be expected to increase as $(\text{flow})^{1.5}$ or perhaps $(\text{flow})^{2}$, indicating that the wear rate should increase in a predictable manner over the range of 50-75%. Thus wear rates which are zero or extremely low at 50% power will remain low at 75% power.

Reference 1 - Blevins, R. D., Flow Induced Vibration, pp. 185-189, Van Nostrand Reinhold, New York, 1977.

3. All tube vibratory responses are small. Therefore, if wear is occurring at the 75% power level or below, each impact event itself must be of relatively low energy. For such low energy impacts to do a significant amount of wear damage to a tube, a large number of such events would be required. The short operating period proposed for McGuire of 30 days is considered to be sufficiently short that no significant tube wear can be expected to occur.

Comparison of McGuire Data with Literature Results

In an attempt to firmly establish the absence of fluidelastic instability as a mechanism for tube vibration in McGuire up to 75% power, a comparison was made with data available with the literature from heat exchanger flow induced vibration testing. Recent work at Argonne National Laboratory sponsored by the Department of Energy has looked in great detail at the phenomenon of fluidelastic instability in industrial heat exchangers. Figures 73 and 74 are from one report of this work - Wambsganss, M. W., Halle, H., and Lawrence, W. P., "Tube Vibration in Industrial Size Test Heat Exchanger (30° Triangular Layout - Six Crosspass Configuration)," ANL-CT-81-42, dated October 1981. This particular report was selected because it represents experience with an actual multitube, multipass, crossflow heat exchanger. In Figure 73, the changes in tube vibration response as the flow increases illustrate graphically the transition from turbulent buffeting of the tube to fluidelastic instability. Note that the vibration changes very abruptly from a broadband characteristic to a sharp, predominantly single frequency response. It can be seen by comparison with the data from the McGuire steam generator (see, for example, Figures 33, 34, and 35) that the McGuire vibration characteristics are not indicative of fluidelastic instability. Note that the ordinates are not to scale on Figure 73. Figure 74 shows the transition from turbulent buffeting to fluidelastic instability in terms of displacement orbits. Note that in the upper figure, peak-to-peak displacements are on the order of 6 mils (.006 inches). The characteristic of the orbit is that it is random in nature, exhibiting no preferred frequency or orientation. Following the transition to fluidelastic instability, the amplitude increases greatly and impacting begins to occur. The orbit also exhibits the predominant frequency which was also evident in the spectra of Figure 73. The large displacements of Figure 74 may be contrasted with Figures 67-72 which show very little tube displacement response at any power level. It is evident from the comparison of the data in the literature on fluidelastic instability that the McGuire tubes do not become unstable but are responding in a broadband, random fashion to turbulent fluid forces surrounding them.

Relationship between Tube Vibration, Wear, and Power Level

There have been several attempts made to relate tube vibration, unit operating power level, and tube wear. Models have been proposed for tube wear as a function of power level, vibration and time at power. In all cases so far, these models have proven to be very conservative and have overestimated the degree to which the tubes would wear. The problem with establishing the relationship between tube wear and operating history has been that no affected unit had operated at a single power level for an extended period of time such that a wear rate at that power level could be established, and there had been uncertainty in the eddy current measurements used as a basis for establishing the total wear which had occurred. The removal and examination of six tubes from Ringhals and Almaraz has reduced the uncertainty in the size of the defects caused by inappropriate application of differential eddy current techniques during the early days of the problem. It is apparent that wear rates are not high in the overwhelming majority of locations in the steam generator, even at 100% power. Because of the undamaged condition of the McGuire steam generators, they are a source of very valuable information about the relationship between operating power level and wear rate. If the steam generators are operated at power levels where the wear rate is low and inspections are performed at intervals to ensure that the wear remains below a level at which plugging the tube would be required, the relation between power level and wear could be determined. Once known, the relationship between operating power, vibration, and wear rate could be used to:

1. Maximize the operating power level for the unmodified steam generators. Besides the economic advantages of the increased power, there would be less impact on many aspects of plant operation.

2. Determine the extent to which the steam generators need to be modified to correct the problem. By providing a measure of what flow velocity is satisfactory for long term operation of the steam generator, considerable insight can be gained into the nature of the vibration phenomenon and greater assurance could be had concerning the adequacy of corrective action. This could lead to significant reduction in the cost and complexity of the modification, and a corresponding reduction in the

radiation exposure which would be incurred in installing the modification in a plant with previous operating history.

3. Increase confidence in tube vibration monitoring as an instrument to avoid regions of excessive tube wear. Identification of what levels of vibration are non-wearing and those which produce unacceptable wear rates would allow operation with greater confidence at all sites where instrumentation is installed. Confidence would also be increased for restricted power operation at those units where significant tube damage has already occurred.

4. Provide a basis for determining the effectiveness of any modification to permit unrestricted full power operation. If non-wearing vibration levels are known from operation of the unmodified units, similar vibration levels at full power after modification would provide additional assurance of the effectiveness of the modification and prevent an excessive number of short operating periods and inspections.

We conclude that these major benefits of operation of McGuire for a short period of time at 75% power justify the small risk of creating minor additional wear.

Proposed Operating Plan for McGuire

Upon receipt of NRC concurrence, Duke would operate McGuire 1 at a power level greater than 50% and less than or equal to 75% for a period not to exceed 720 hours, then return to 50% power until no later than the first week in July 1982. At that time the unit would be shutdown and a steam generator inspection identical to that performed in March 1982 would be performed.

Assessment of the Impact of Operating Plan

Based on the new conservative assumption of a defect volume of 4×10^{-4} cubic inches, a new wear rate for McGuire can be established for operation at 75% power. The details of how this wear rate is calculated, and the conservatism in that method, are discussed in the submittal of March 16, 1982. The new postulated wear rate for McGuire at 75% power is 1.23×10^{-6} cubic inches per hour. The total wear for this period is

$$720 \text{ hours} \times 1.23 \times 10^{-6} \frac{\text{in}^3}{\text{hour}} = 8.89 \times 10^{-4} \text{ in}^3$$

When added to the previous postulated defect of 4×10^{-4} in^3, the worst defect in the McGuire steam generator would have a volume of 1.29×10^{-3} in^3. Since only four tubes show evidence of previous wear, this defect size would apply only to those four tubes. The other preheater tubes have shown no measurable wear after 324 hours at 75% and above. They would not be expected to approach near this value. Consultation of Figure 1 to determine possible through-wall depth associated with defects in this range shows that a depth of 10 mils (23%) may be considered an upper bound for the largest single defect which would exist in the McGuire steam generators after 720 hours at 75% plus all of the previous operating history, up to the shutdown date of July 4, 1982. This 23% penetration is well below the plugging limit at which tube integrity under accident conditions becomes a concern. In summary, there is no safety concern associated with the proposed operating plan for McGuire.

In assessing the long term impact of tube wear on the McGuire steam generators, the following factors were considered:

1. Because the preheater chemical environment is that of the entering feed-water rather than that of the steam generator bulk water, the corrosion effects at the entrance to the preheater are less severe. The better corrosion environment of tubes in the preheater entrance will tend to mitigate any slight damage done by tube wear.

2. Once the modification has been made, tube wear in this area will cease. The cessation of wear will be verified during the periodic eddy current inspections required by the McGuire Technical Specifications. This is in contrast to other tube degradation mechanisms which continue for the life of the steam generator.

3. The four tubes affected so far could all be plugged without a detrimental effect on steam generator performance. Thus if long term experience shows that plugging is required, it can be done in a timely manner.

4. Defects as large as 50% through wall (over twice as big in depth and 6-7 times bigger in volume than the upper bound defect for McGuire) have been left in service in both Ringhals 3 and Almaraz. Thus any tendency of more heavily worn tubes (below the plugging limit) to become unreliable in service will be found in those units before McGuire is affected.

We conclude that there will be no adverse effects on the long term integrity of the steam generator tubes in McGuire if wear as large as that estimated by our upper bound were to occur as the result of our proposed operating plan.

Summary and Conclusions

The following conclusions summarize our additional justification for the operation of McGuire at 75% power:

1. The uncertainty in the size of the maximum defect created in any McGuire steam generator is resolved by increasing our size estimate to 4.0×10^{-4} cubic inches. This size is justified by calculations and analysis using several independent methods. We conclude that this volume represents a very conservative upper bound for the largest defect in McGuire; our best estimate of the size of this defect is less than 1.5×10^{-4} cubic inches.

2. Additional justification was provided for selection of 1.0×10^{-3} cubic inches as a bounding volume for additional wear. Most notably, actual defect data from two additional removed tubes from Almaraz have been shown to be consistent with the previous data. Figure 1 depicts the

consistency of all of the defect data, including the leaking defect from Ringhals 3.

3. Analysis has been provided for vibration data from accelerometers installed inside tubes during our March 1982 outage. This analysis shows that the vibration of these tubes is relatively low, even at 75% power, and that the increase in tube vibration as power level increases is a predictable function of power. We have demonstrated by comparison with experimental data that the magnitude and characteristics of the vibration in McGuire is consistent with tube buffeting by turbulent fluid forces and that there is no evidence of fluidelastic instability or of a threshold of high vibrational activity.

4. Based on the analysis of tube vibration data and considering the previous operating history of McGuire, tube wear rates at power levels up to and including 75% are zero or very small, and McGuire may be operated safely for a period of time at 75% in order to establish the relationship between power level, tube vibration, and wear. Knowledge of a safe operating level for extended operation, and getting at least one more point on the curve which relates power level, tube vibration, and wear, will result in benefits both to the utilities and to those designing the permanent corrective action.

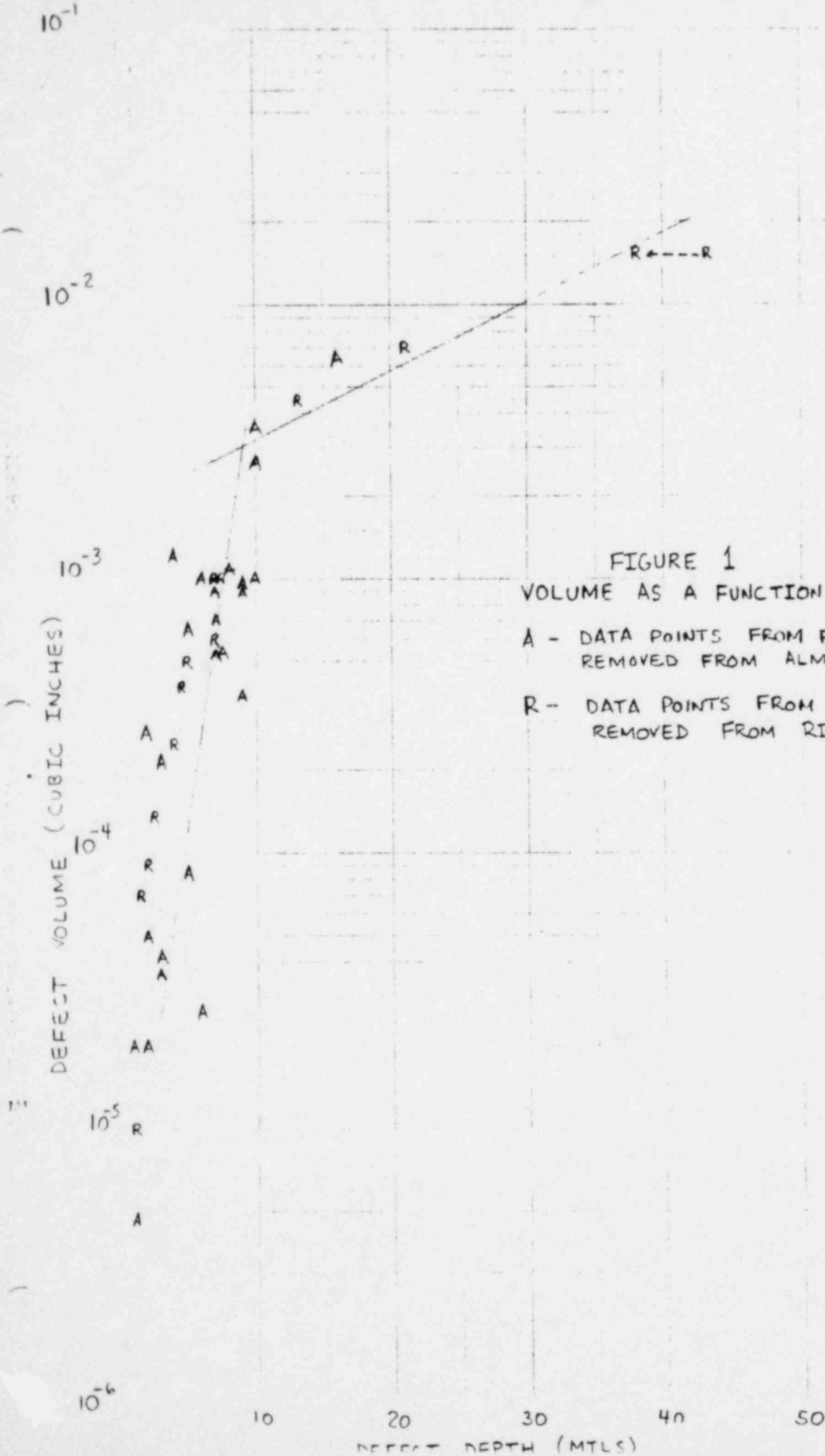
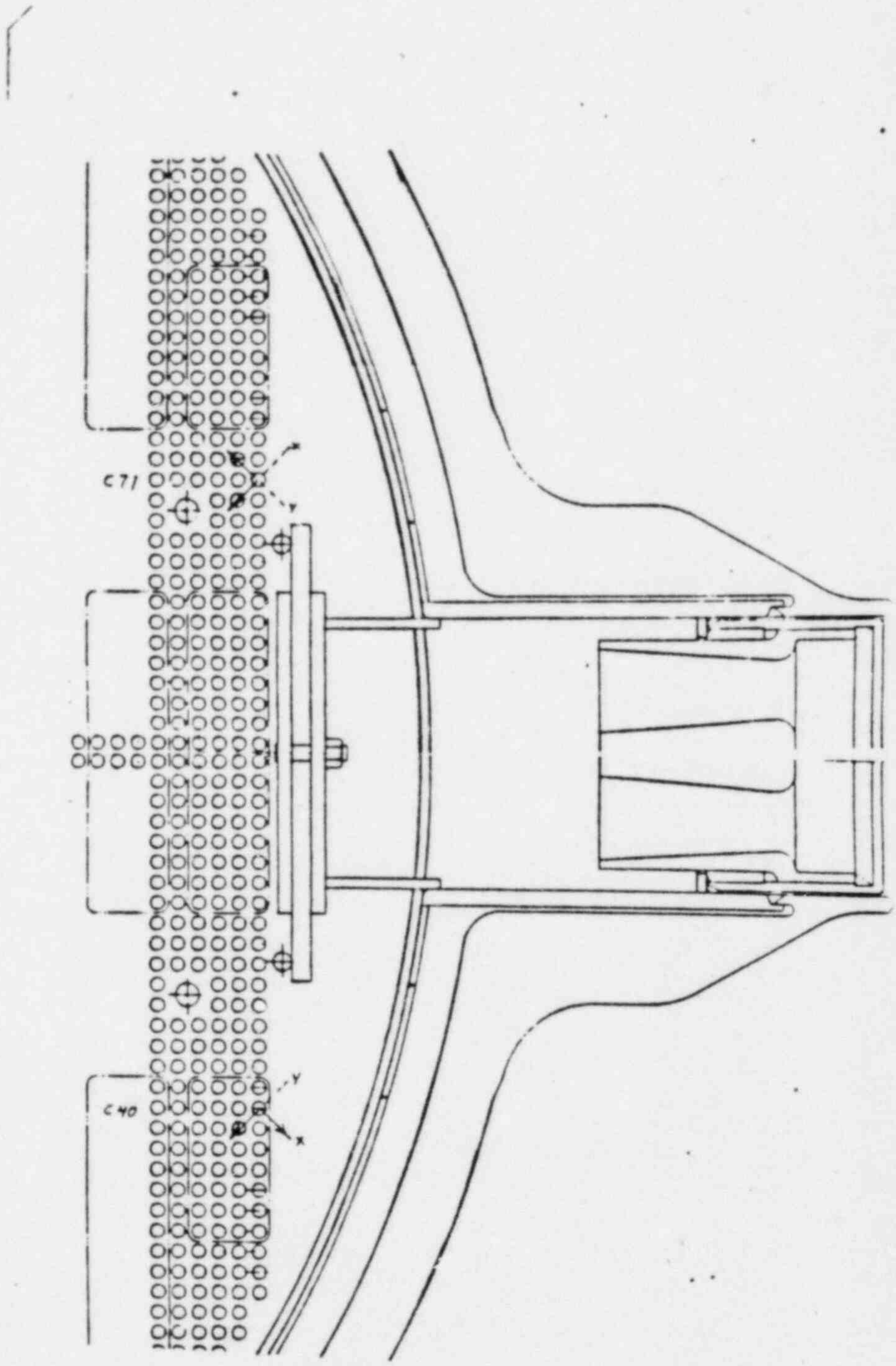


FIGURE 1

VOLUME AS A FUNCTION OF MAX. DEPTH

A - DATA POINTS FROM FOUR TUBES REMOVED FROM ALMARAZ

R - DATA POINTS FROM TWO TUBES REMOVED FROM RINGHALS

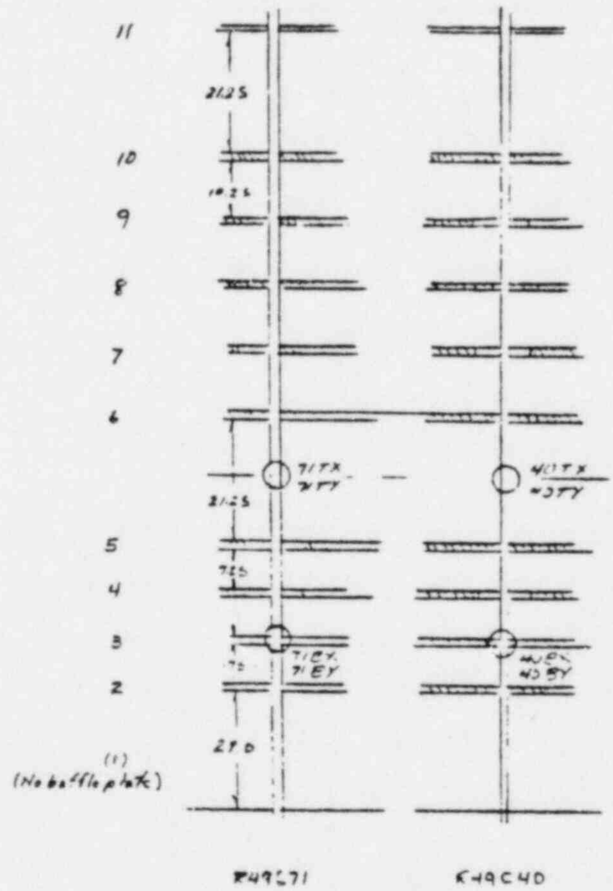


[illegible]

Accelerometer [illegible]

[illegible] View

Figure 2



McGuire
Accelerometer Locations
Elevation View
Figure 3

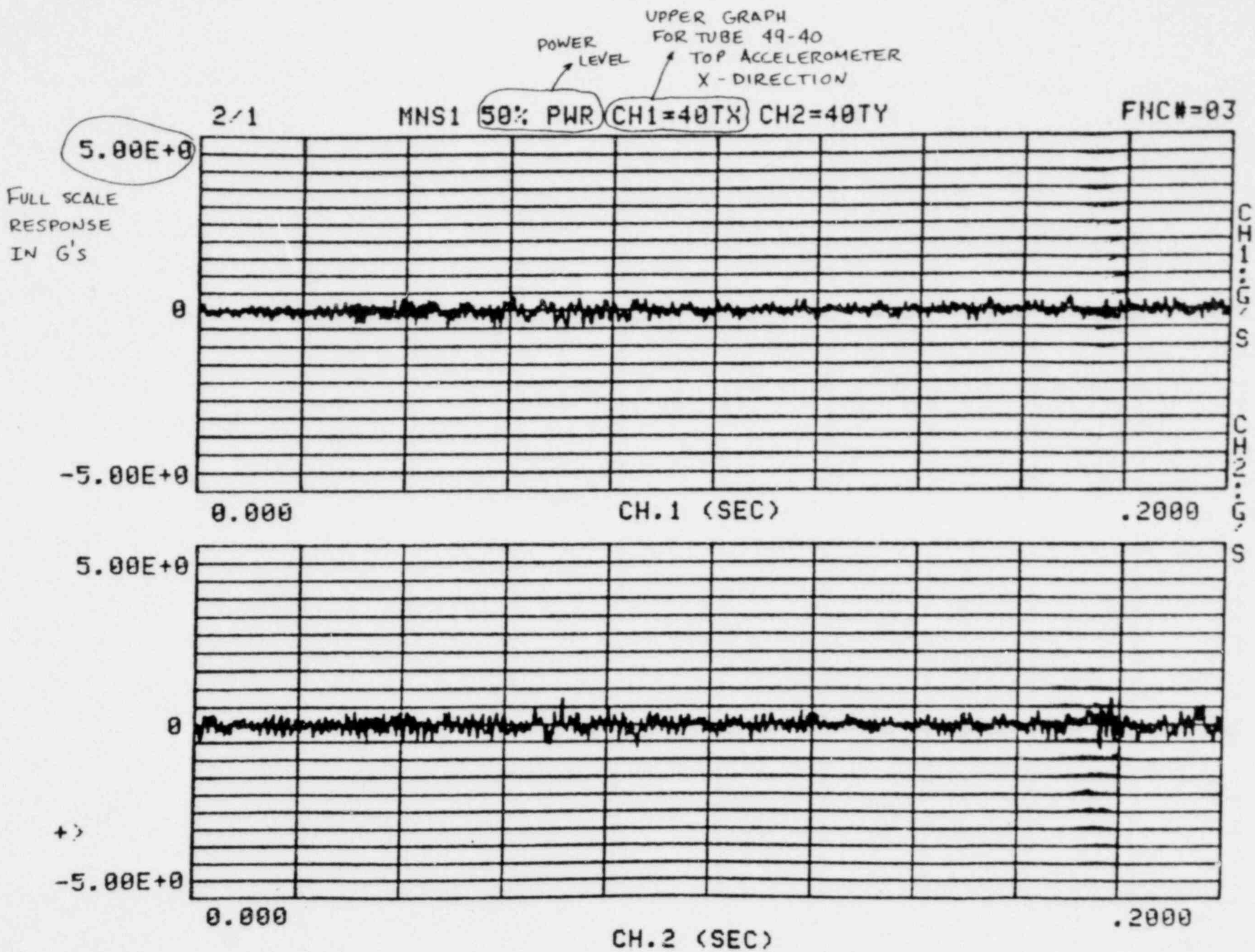
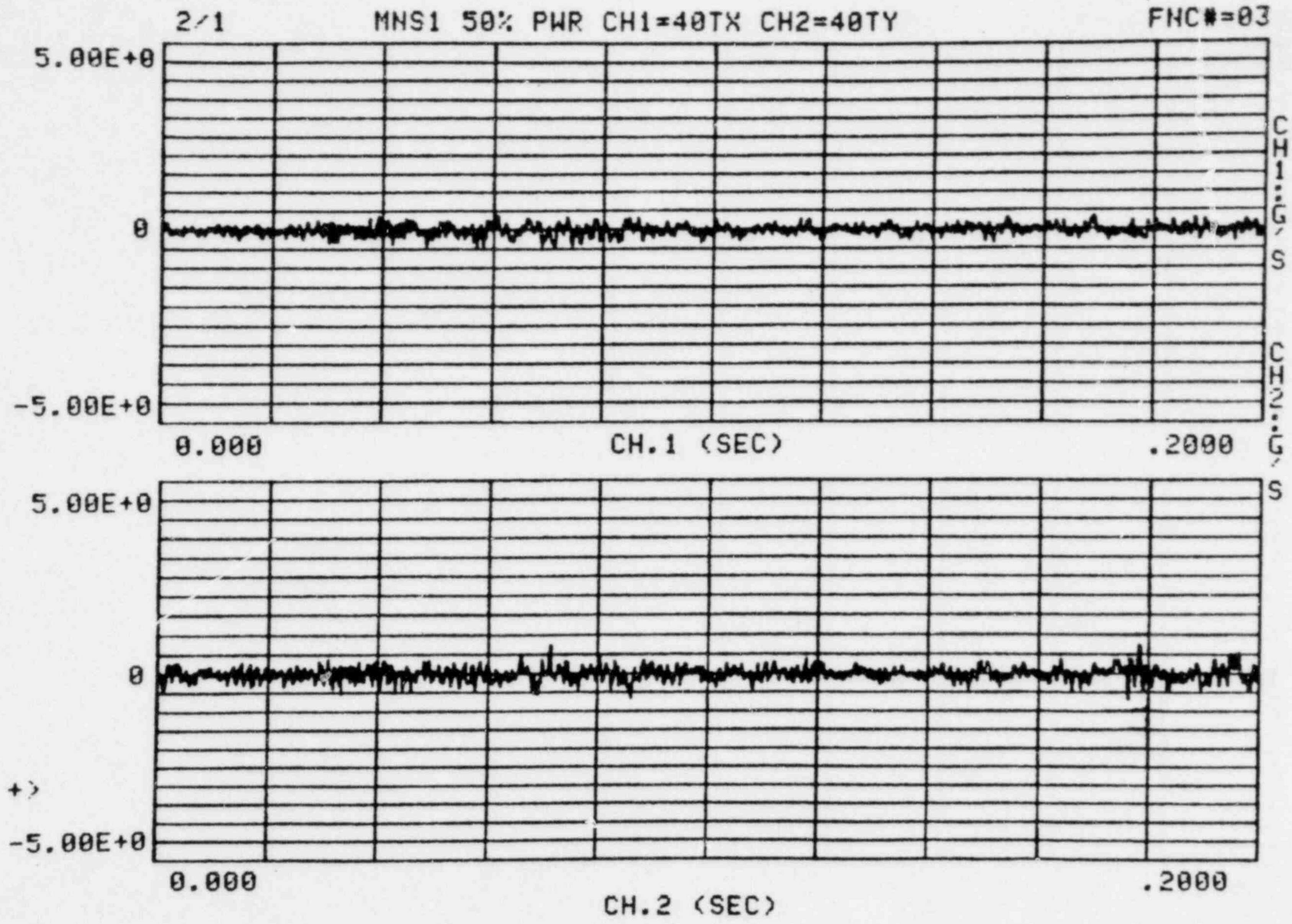

UPPER GRAPH
FOR TUBE 49-40
TOP ACCELEROMETER
X - DIRECTION
POWER
LEVEL
2/1
MNS1 50% PWR CH1=40TX CH2=40TY
FNC#=03
5.00E+0
FULL SCALE
RESPONSE
IN G's
0
-5.00E+0
0.000
CH.1 (SEC)
.2000
CH1:G/S
CH2:G/S
5.00E+0
0
-5.00E+0
0.000
.2000
CH.2 (SEC)

FIGURE 4


2/1
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FNC#=03
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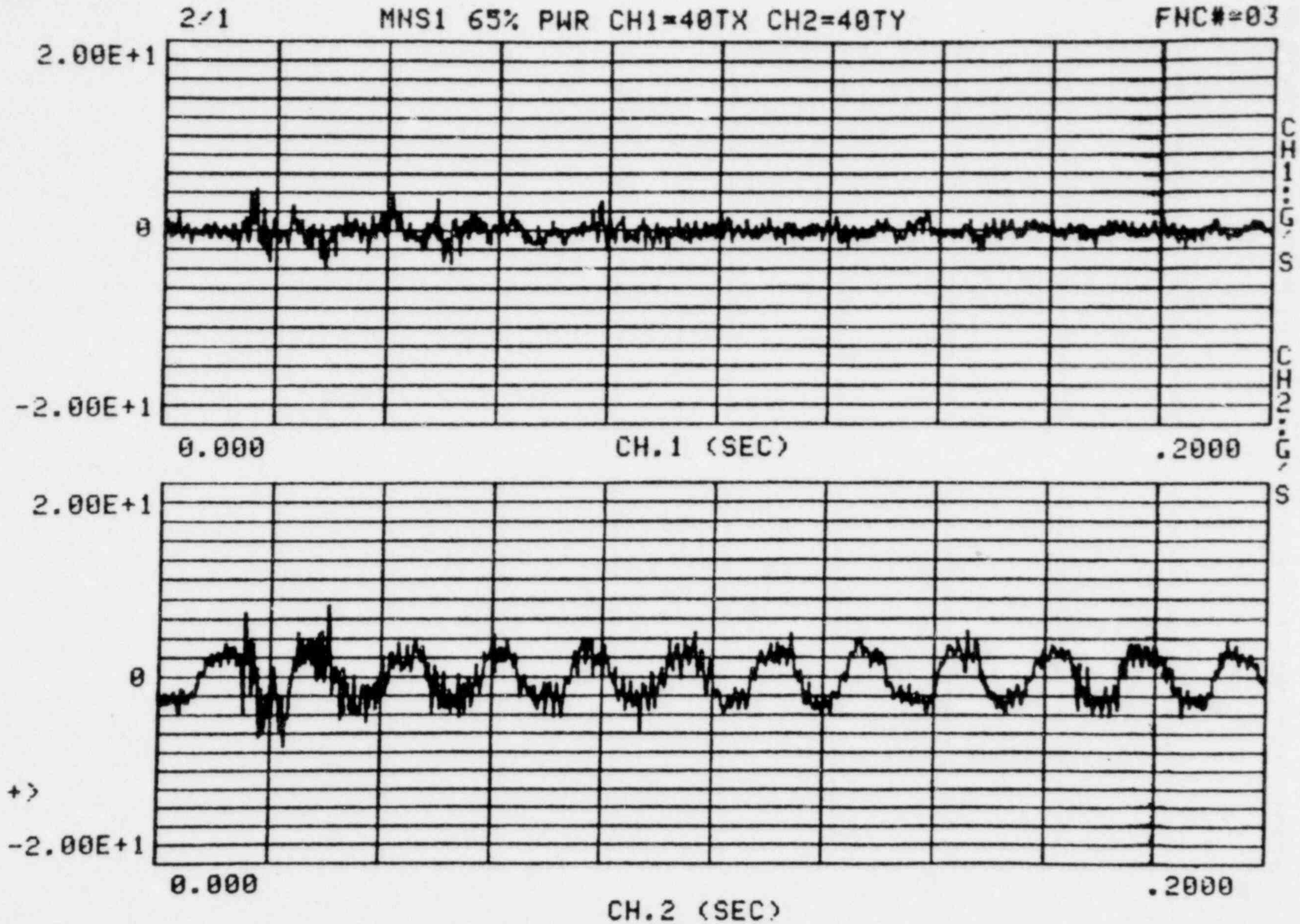
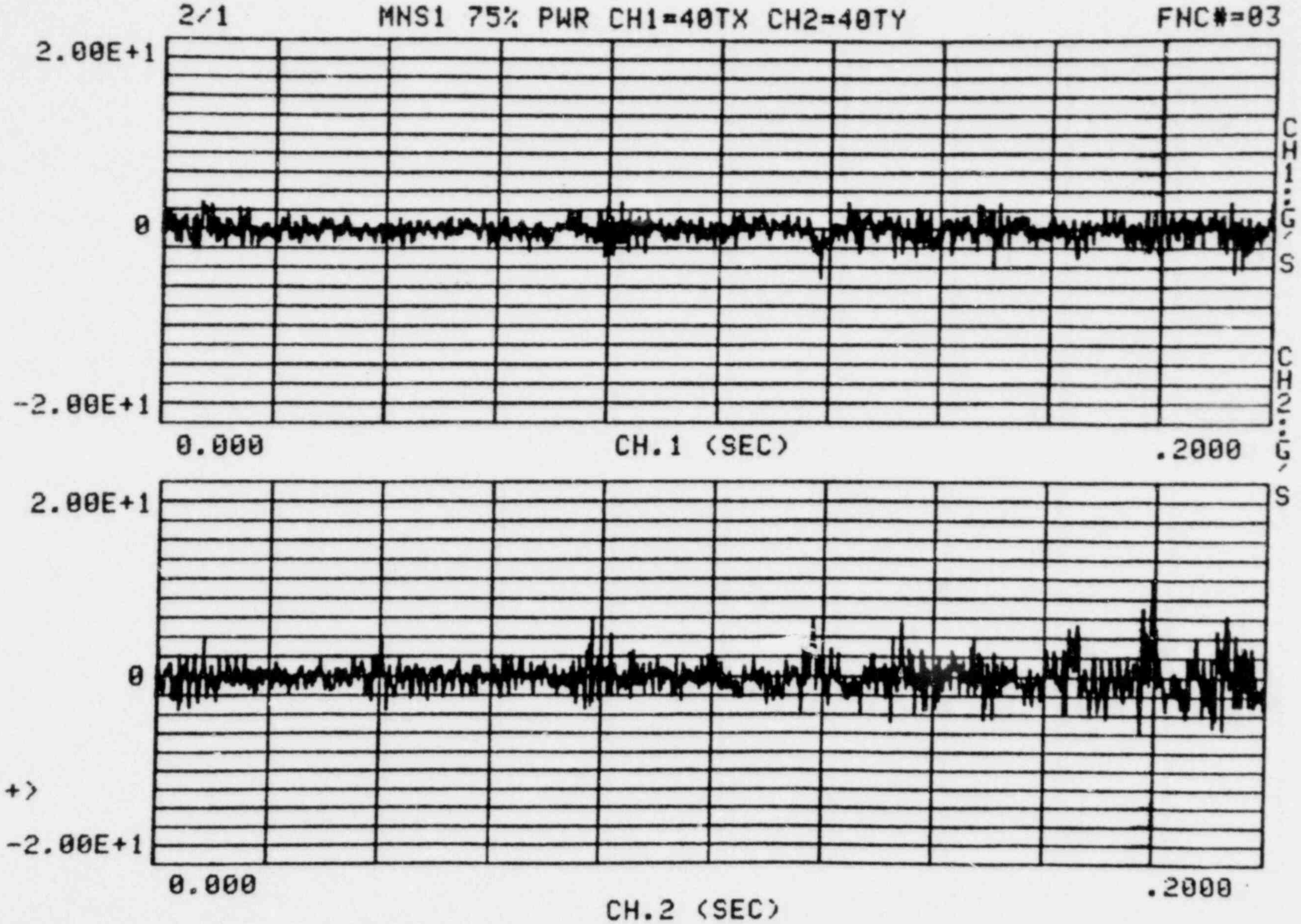
0
-5.00E+0
0.000
CH.1 (SEC)
.2000
CH1:G/S
CH2:G/S
5.00E+0
0
-5.00E+0
0.000
.2000
CH.2 (SEC)

FIGURE 5



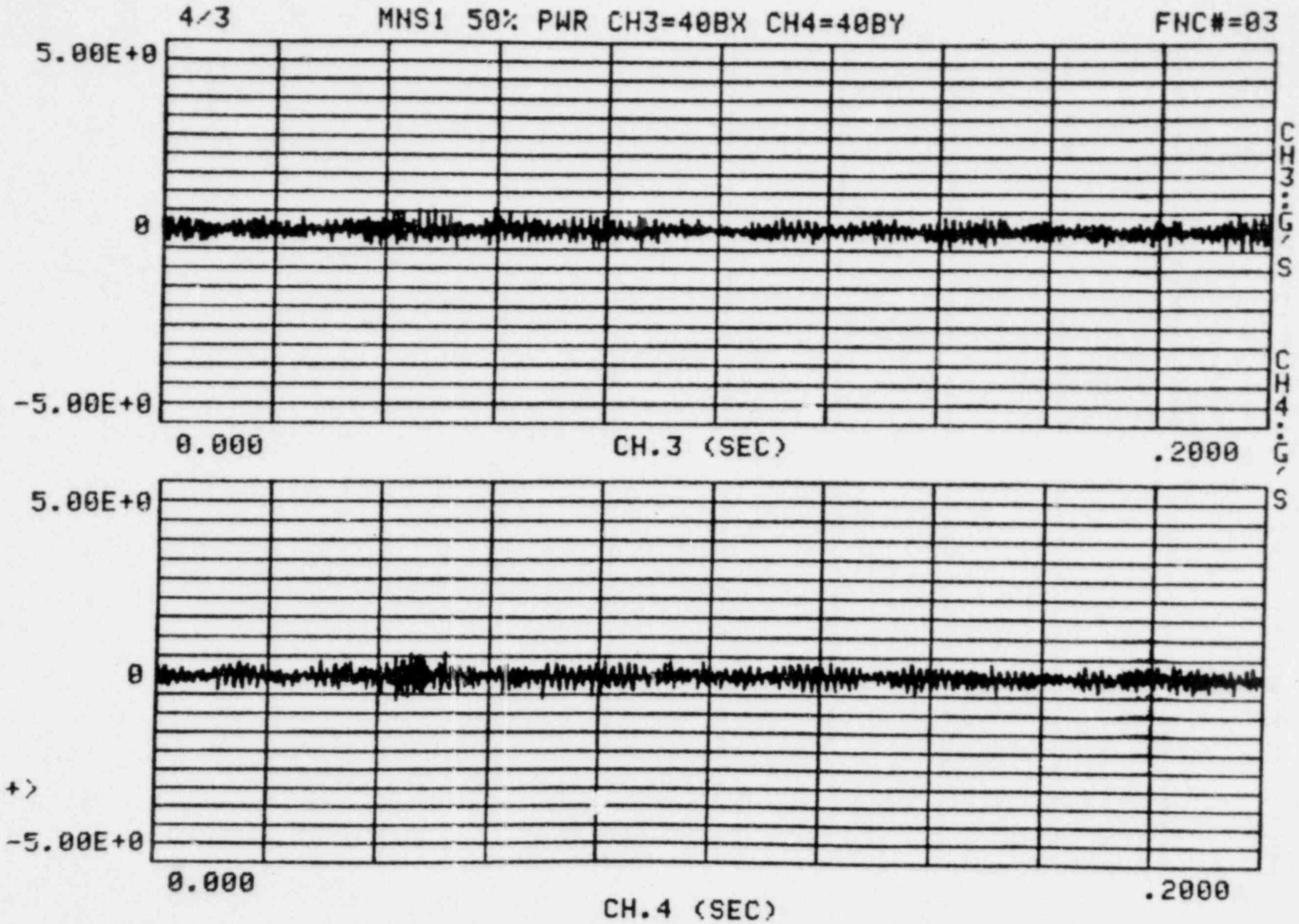
2/1
MNS1 65% PWR CH1=40TX CH2=40TY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.1 (SEC)
.2000
CH1:G/S
CH2:G/S
2.00E+1
0
+>
-2.00E+1
0.000
.2000
CH.2 (SEC)

FIGURE 6



2/1
MNS1 75% PWR CH1=40TX CH2=40TY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.1 (SEC)
.2000
CH1:G/S
CH2:G/S
2.00E+1
0
+>
-2.00E+1
0.000
.2000
CH.2 (SEC)

FIGURE 7



4/3
MNS1 50% PWR CH3=40BX CH4=40BY
FNC#=03
5.00E+0
0
-5.00E+0
0.000
CH.3 (SEC)
.2000
CH3:G/S
CH4:G/S
5.00E+0
0
-5.00E+0
0.000
CH.4 (SEC)
.2000

FIGURE 8

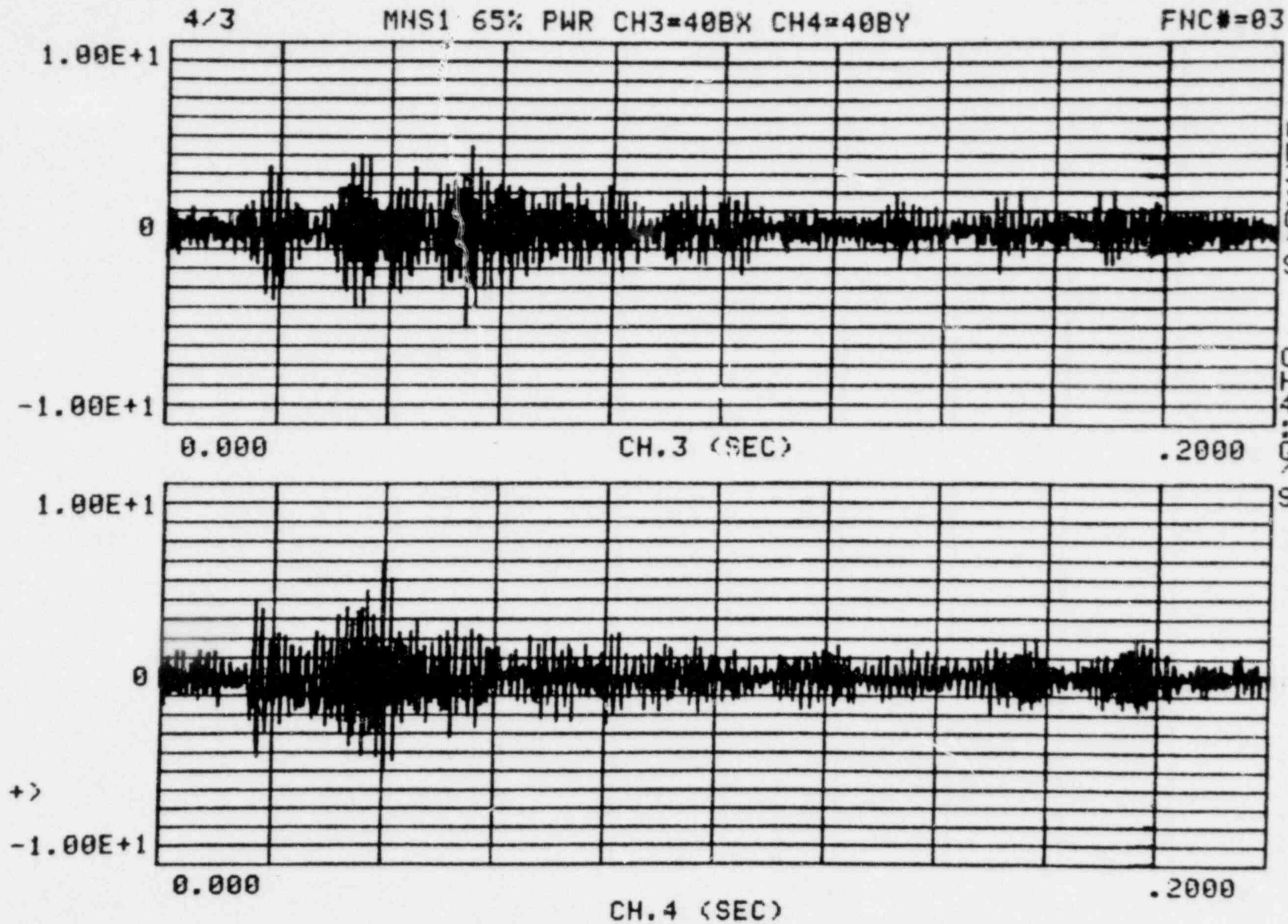
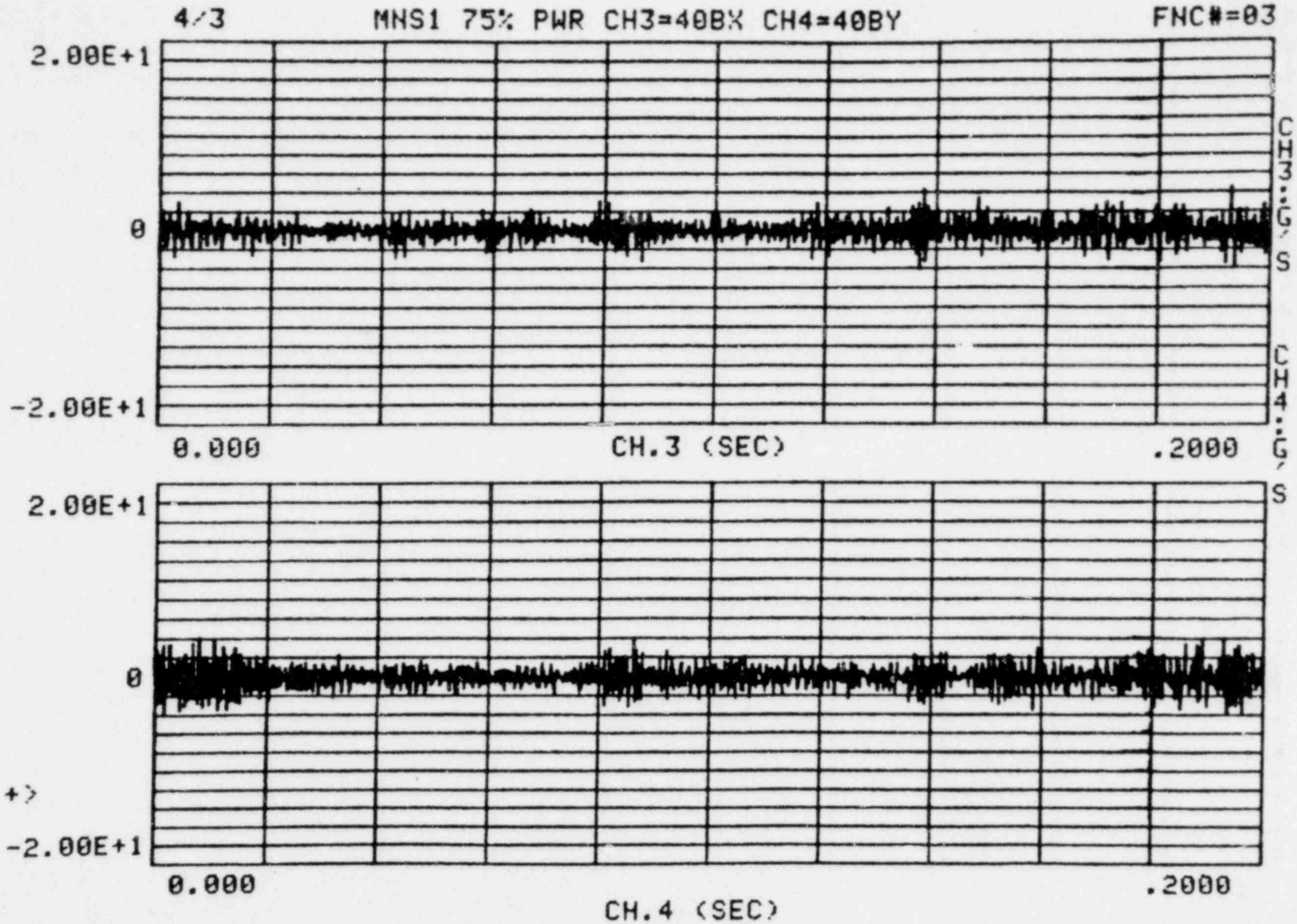

4/3
MNS1 65% PWR CH3=40BX CH4=40BY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.3 (SEC)
.2000
CH3:G/S
CH4:G/S
1.00E+1
0
+>
-1.00E+1
0.000
CH.4 (SEC)
.2000

FIGURE 9



4/3
MNS1 75% PWR CH3=40BX CH4=40BY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.3 (SEC)
.2000
CH3:G's
CH4:G's
2.00E+1
0
+>
-2.00E+1
0.000
.2000
CH.4 (SEC)

FIGURE 10

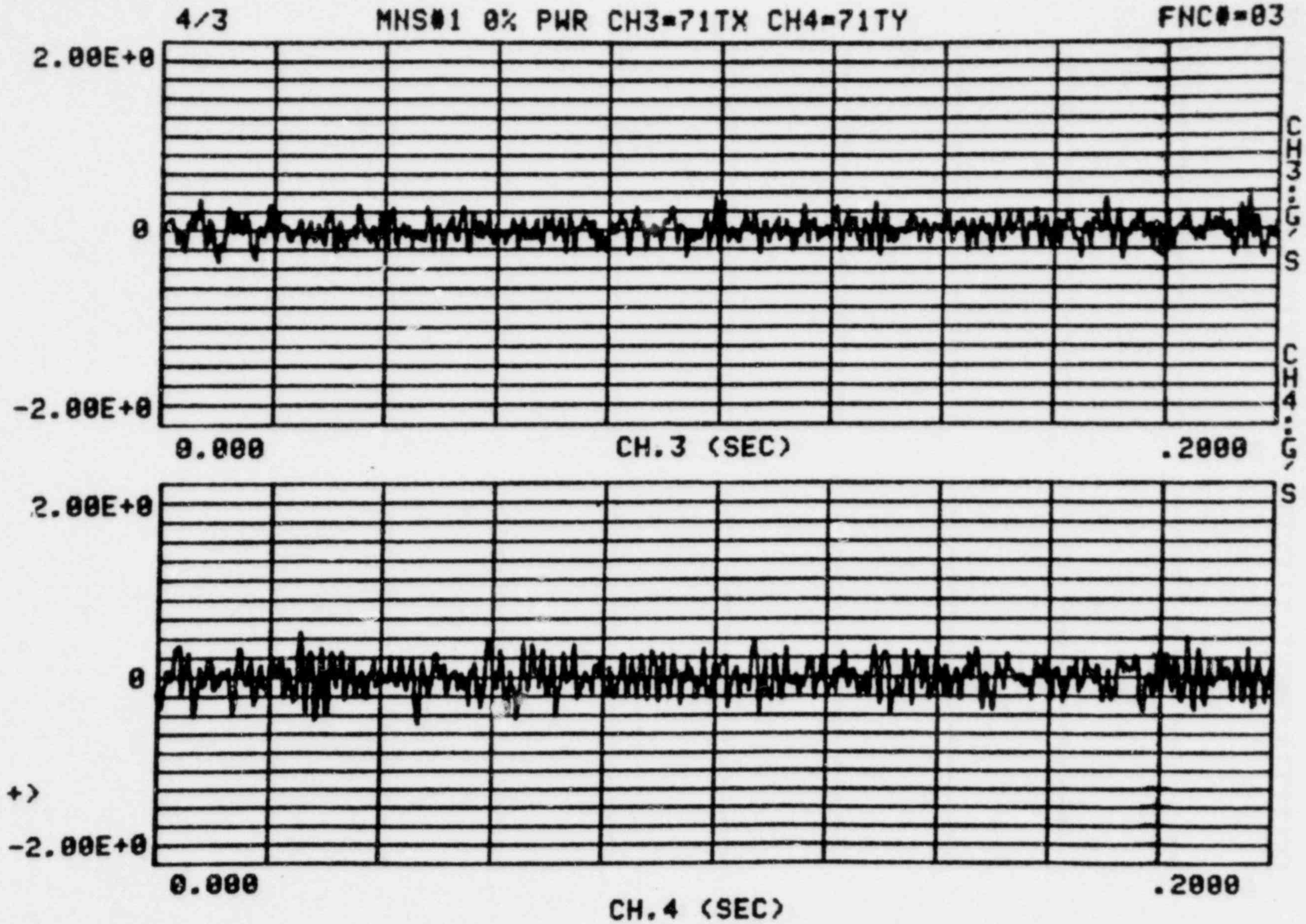

4/3
MNS#1 0% PWR CH3=71TX CH4=71TY
FNC#=03
2.00E+0
0
-2.00E+0
0.000
CH.3 (SEC)
.2000
CH3:G'S
CH4:G'S
2.00E+0
0
+>
-2.00E+0
0.000
.2000
CH.4 (SEC)

FIGURE 11

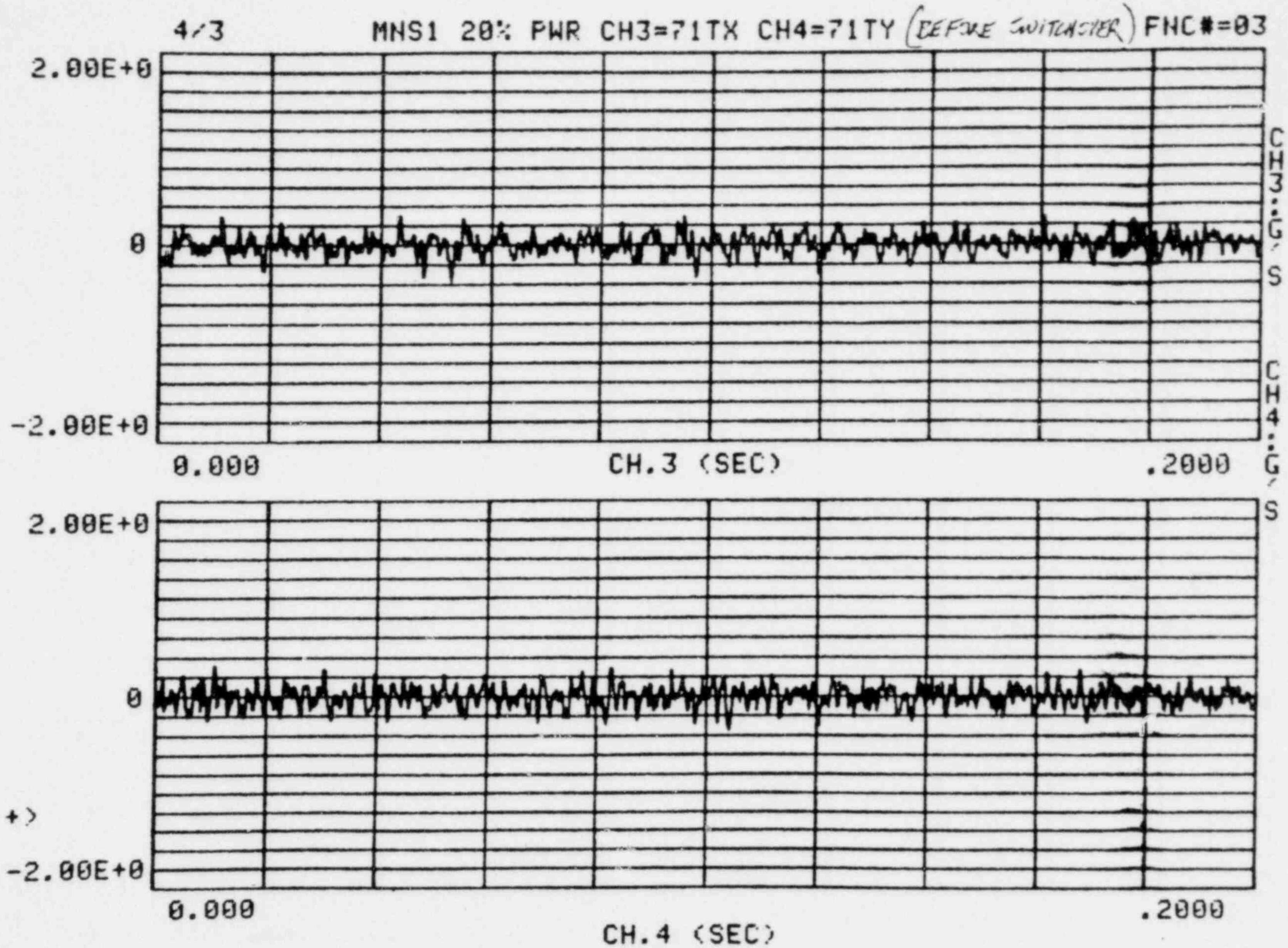

4/3 MNS1 20% PWR CH3=71TX CH4=71TY (BEFORE SWITCHOVER) FNC#=03
2.00E+0
0
-2.00E+0
0.000
CH.3 (SEC)
.2000
CH3:G/S
CH4:G/S
2.00E+0
0
+>
-2.00E+0
0.000
.2000
CH.4 (SEC)

FIGURE 12

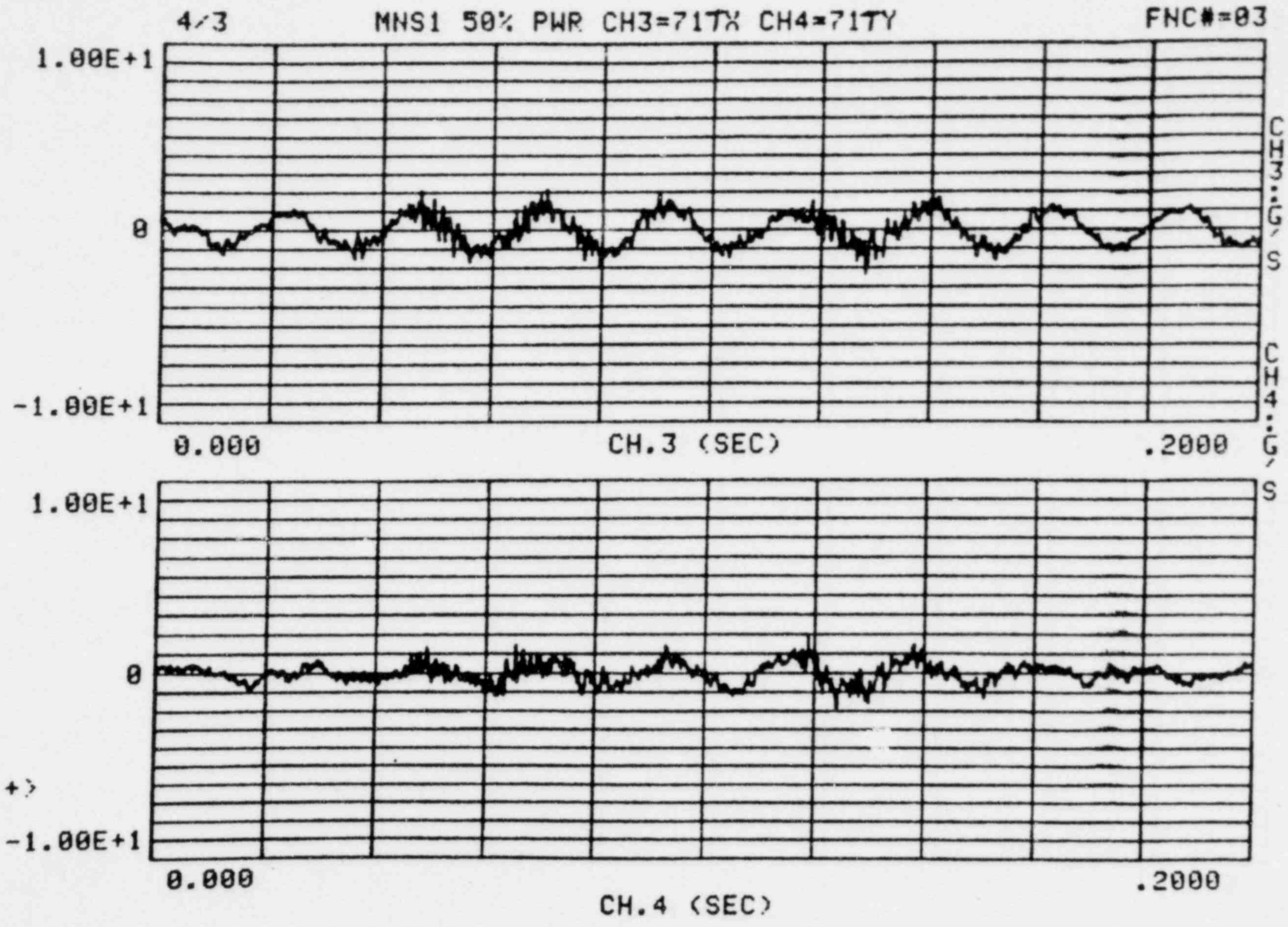
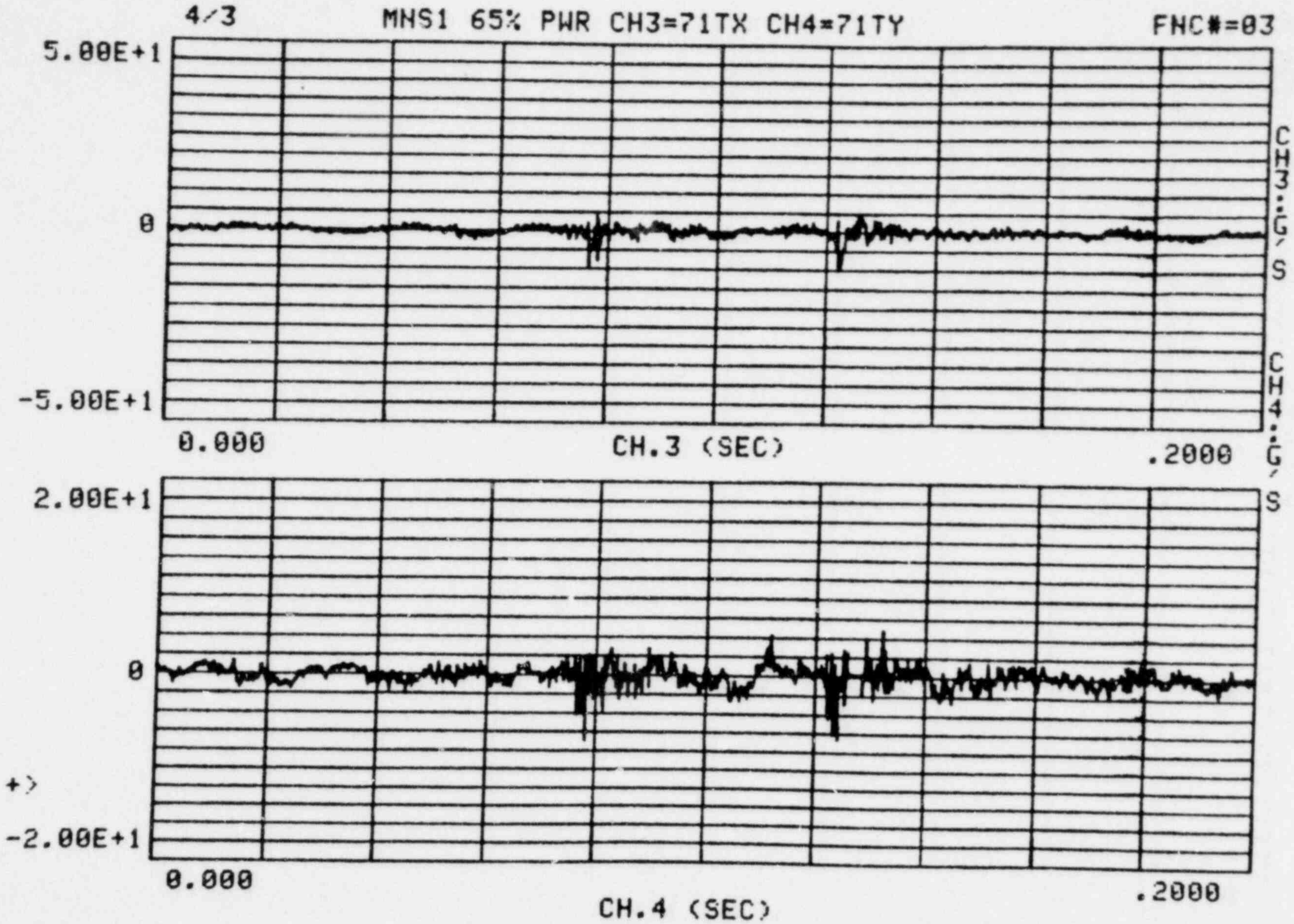

4/3
MNS1 50% PWR CH3=71TX CH4=71TY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.3 (SEC)
.2000
CH3:G/S
CH4:G/S
1.00E+1
0
+>
-1.00E+1
0.000
.2000
CH.4 (SEC)

FIGURE 13



4/3
MNS1 65% PWR CH3=71TX CH4=71TY
FNC#=03
5.00E+1
0
-5.00E+1
0.000
CH.3 (SEC)
.2000
CH3:G/S
CH4:G/S
2.00E+1
0
+>
-2.00E+1
0.000
.2000
CH.4 (SEC)

FIGURE 14

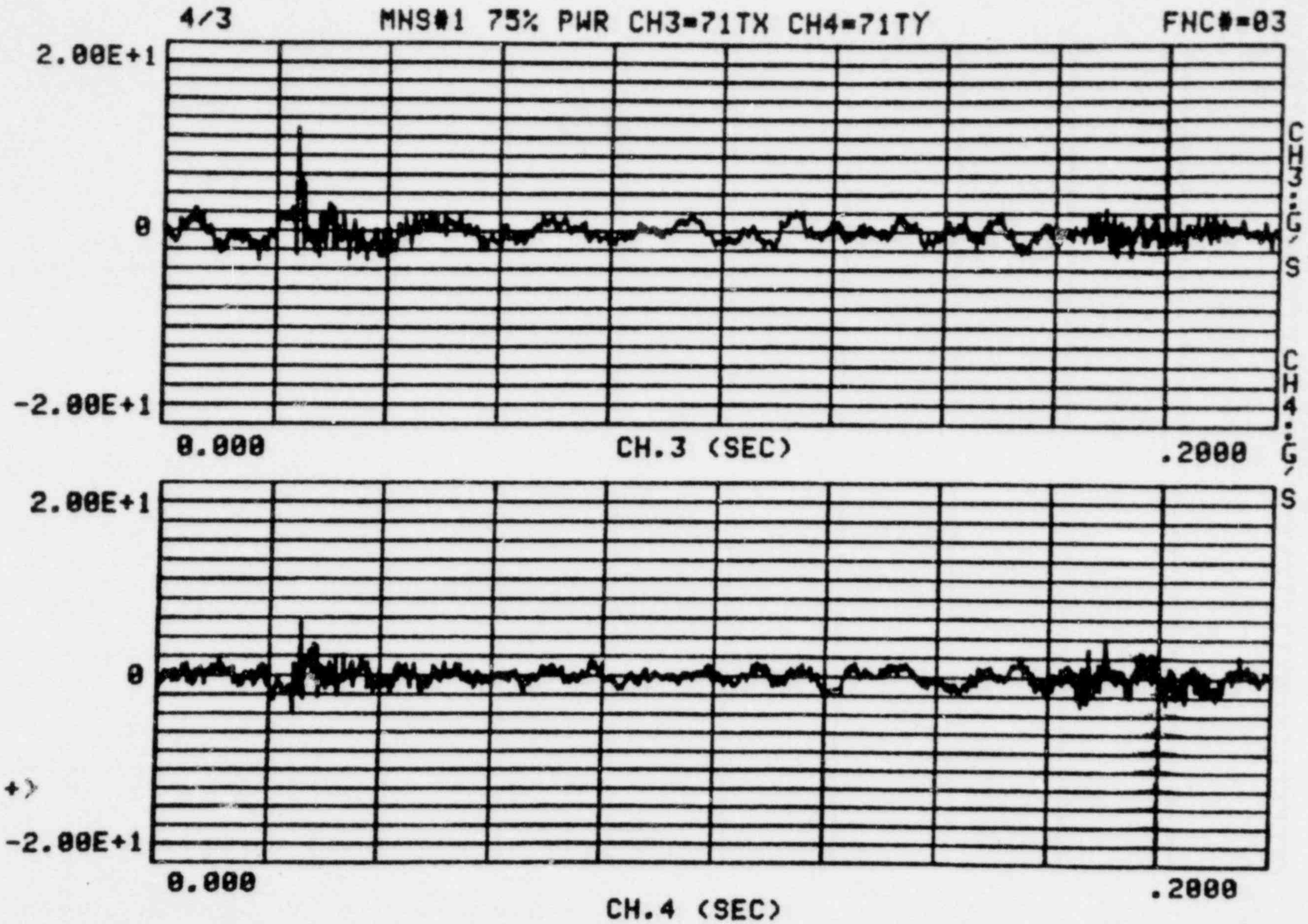

4/3
MNS#1 75% PWR CH3=71TX CH4=71TY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.3 (SEC)
.2000
CH3:G/S
CH4:G/S
2.00E+1
0
-2.00E+1
0.000
CH.4 (SEC)
.2000

FIGURE 15

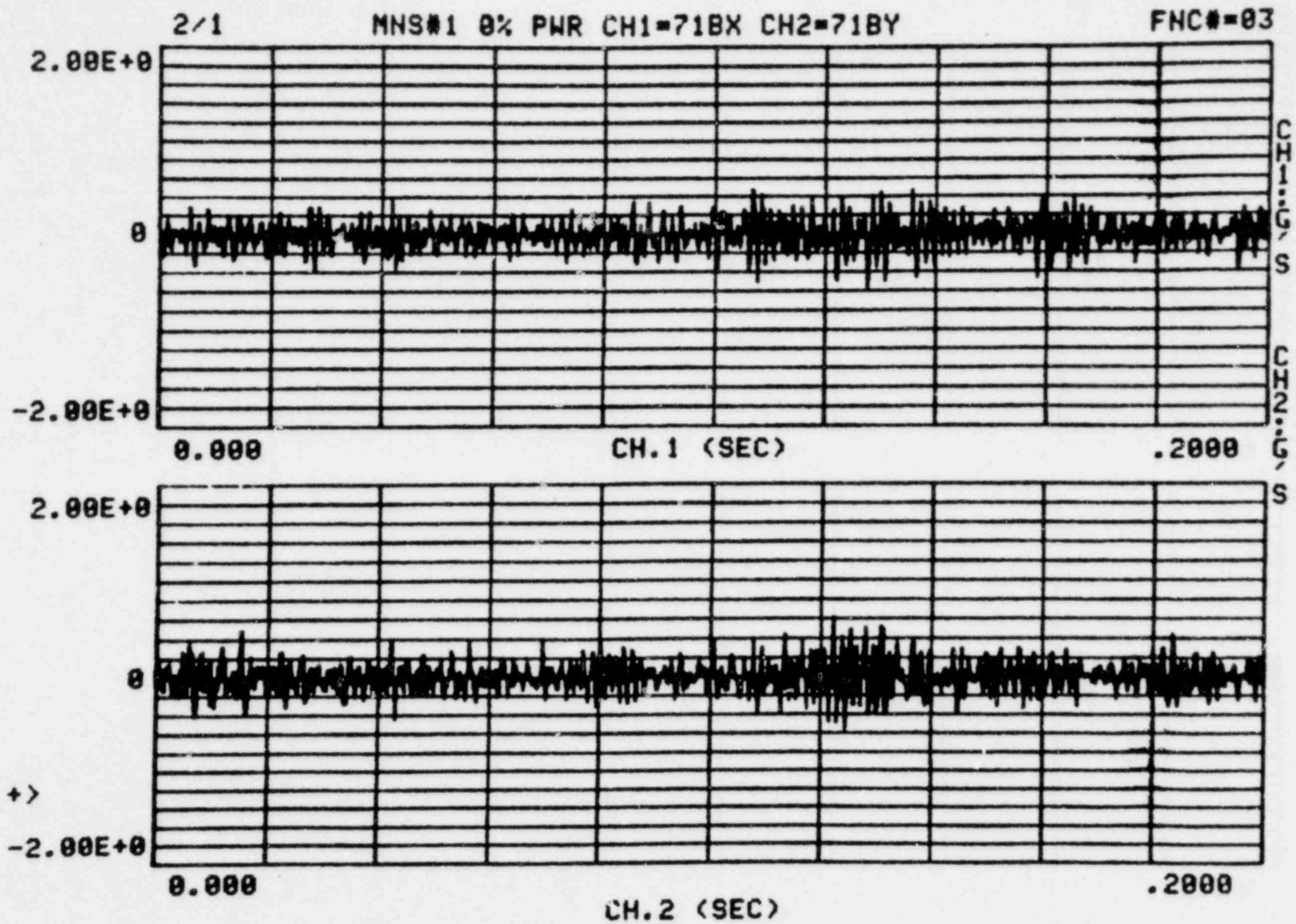
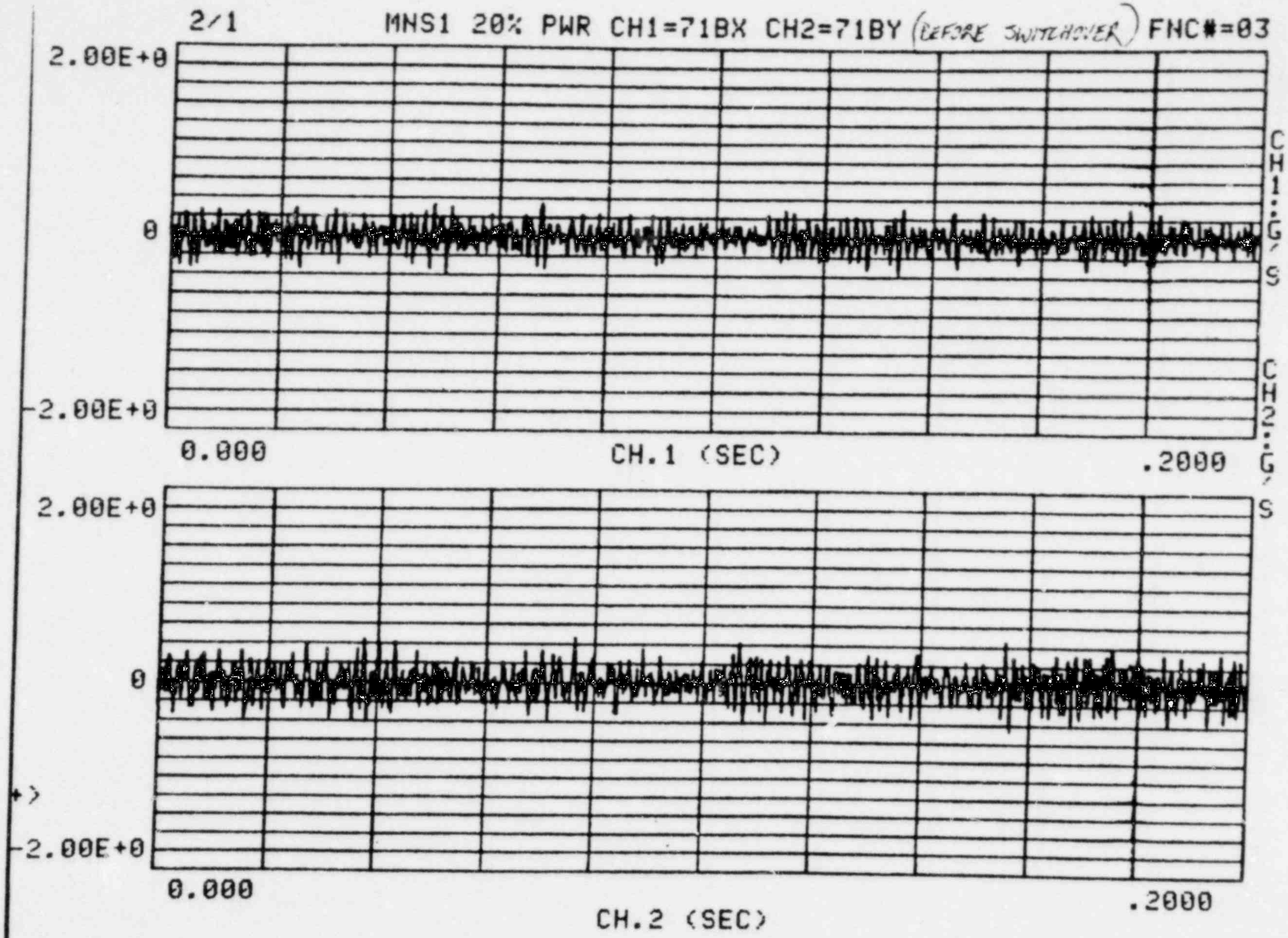
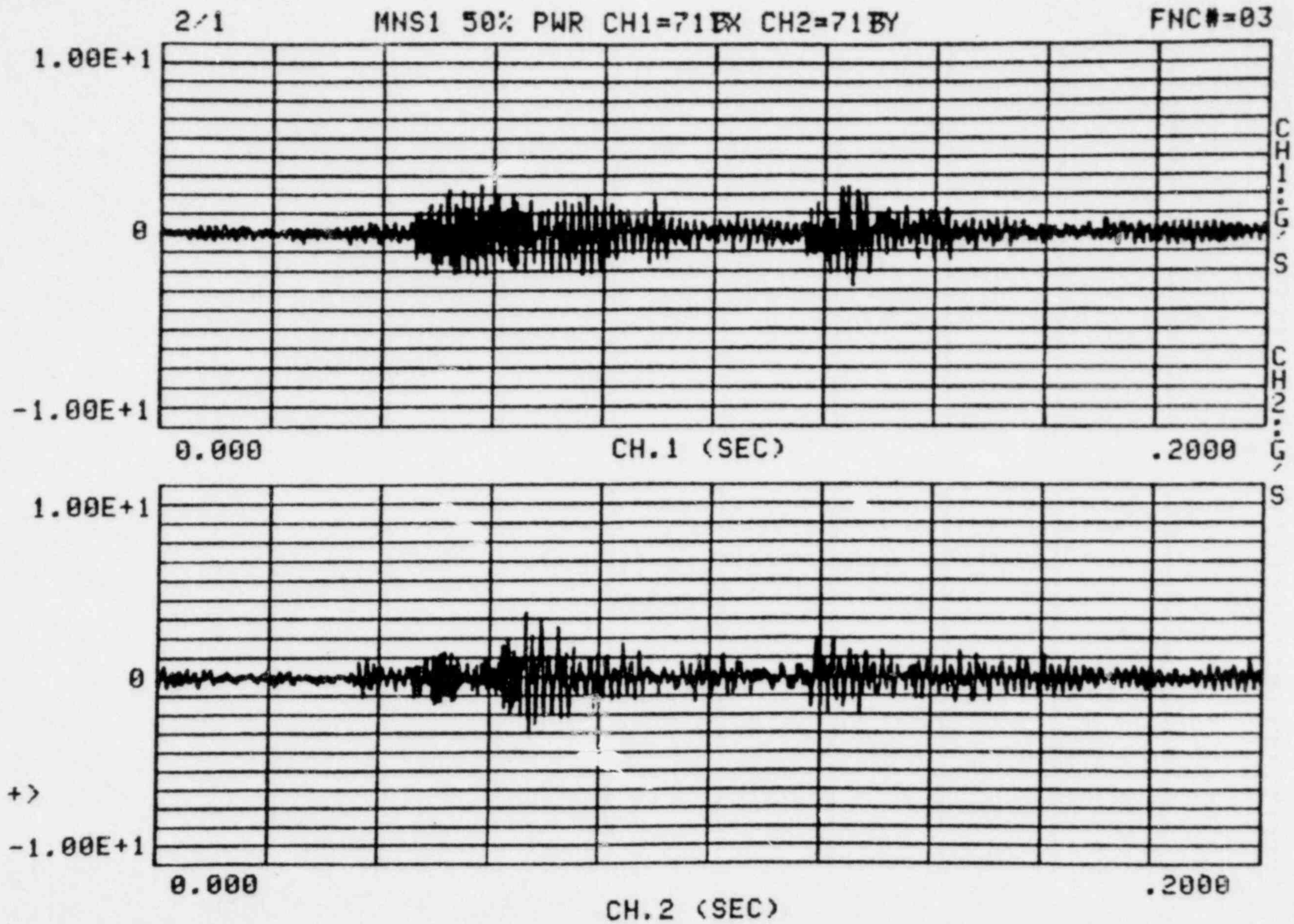

2/1
MNS#1 0% PWR CH1=71BX CH2=71BY
FNC#=03
2.00E+0
0
-2.00E+0
0.000
CH.1 (SEC)
.2000
CH1:G'S
CH2:G'S
2.00E+0
0
-2.00E+0
+>
0.000
.2000
CH.2 (SEC)

FIGURE 16



2/1
MNS1 20% PWR CH1=71BX CH2=71BY (BEFORE SWITCHOVER) FNC#=03
2.00E+0
0
-2.00E+0
0.000
CH.1 (SEC)
.2000
CH1: G's
2.00E+0
0
-2.00E+0
0.000
CH.2 (SEC)
.2000
CH2: G's

FIGURE 17



2/1
MNS1 50% PWR CH1=71BX CH2=71BY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.1 (SEC)
.2000
CH1:G/S
CH2:G/S
1.00E+1
0
+>
-1.00E+1
0.000
.2000
CH.2 (SEC)

FIGURE 18

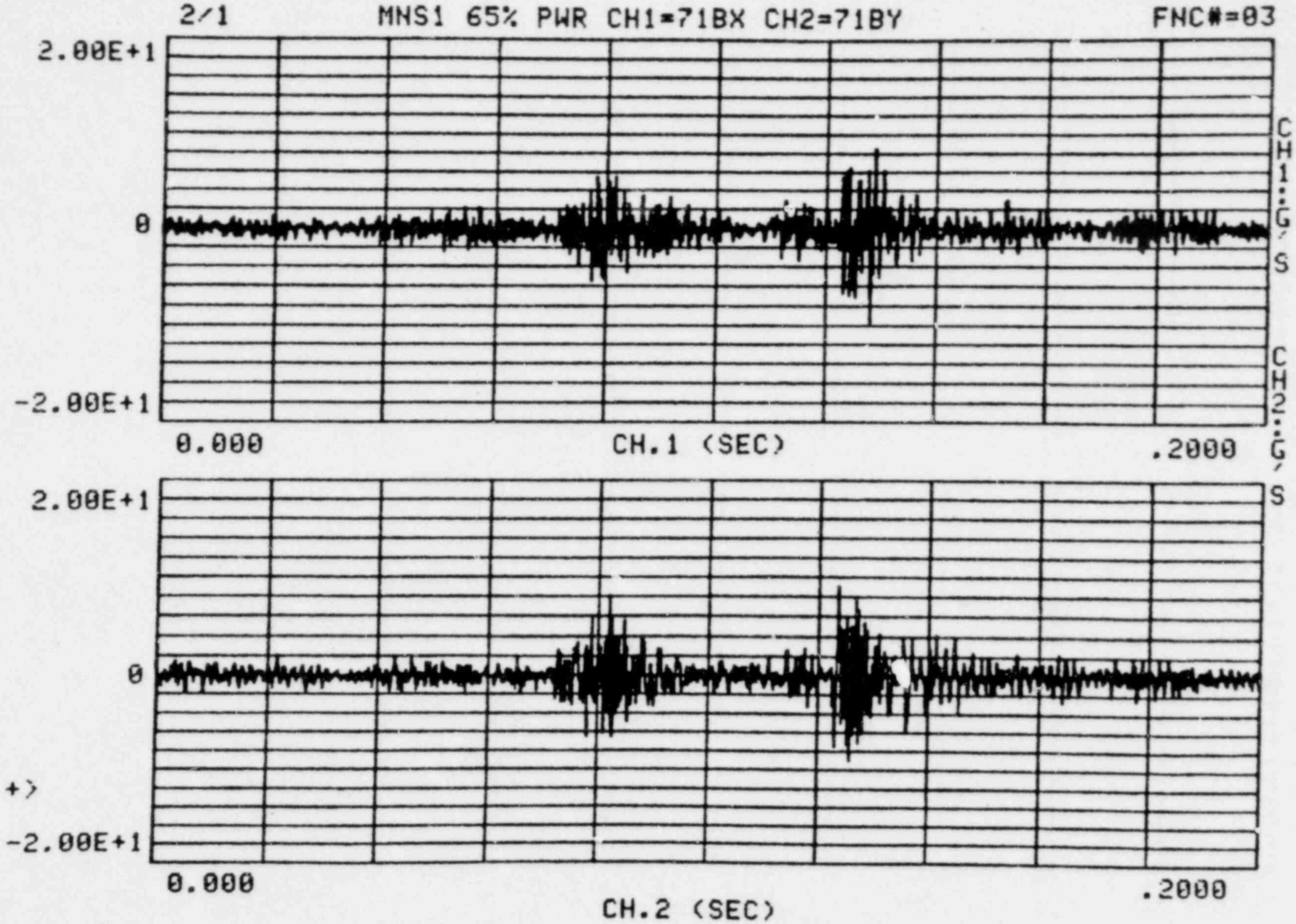

2/1
MNS1 65% PWR CH1=71BX CH2=71BY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.1 (SEC)
.2000
CH1:G/S
CH2:G/S
2.00E+1
0
+>
-2.00E+1
0.000
.2000
CH.2 (SEC)

FIGURE 19

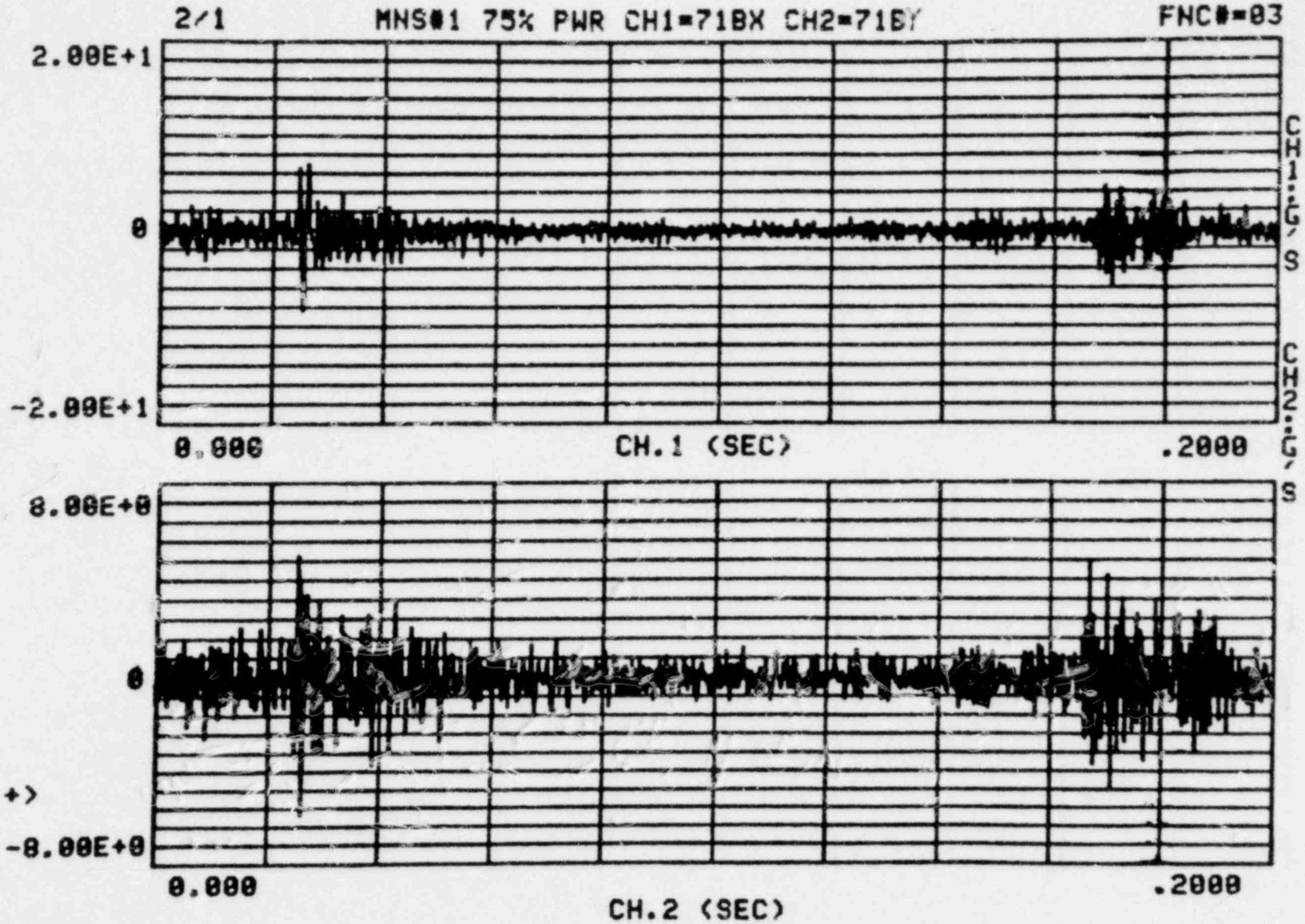

2/1
MNS#1 75% PWR CH1=71BX CH2=71BY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.1 (SEC)
.2000
CH1:G's
CH2:G's
8.00E+0
0
+>
-8.00E+0
0.000
.2000
CH.2 (SEC)

FIGURE 20

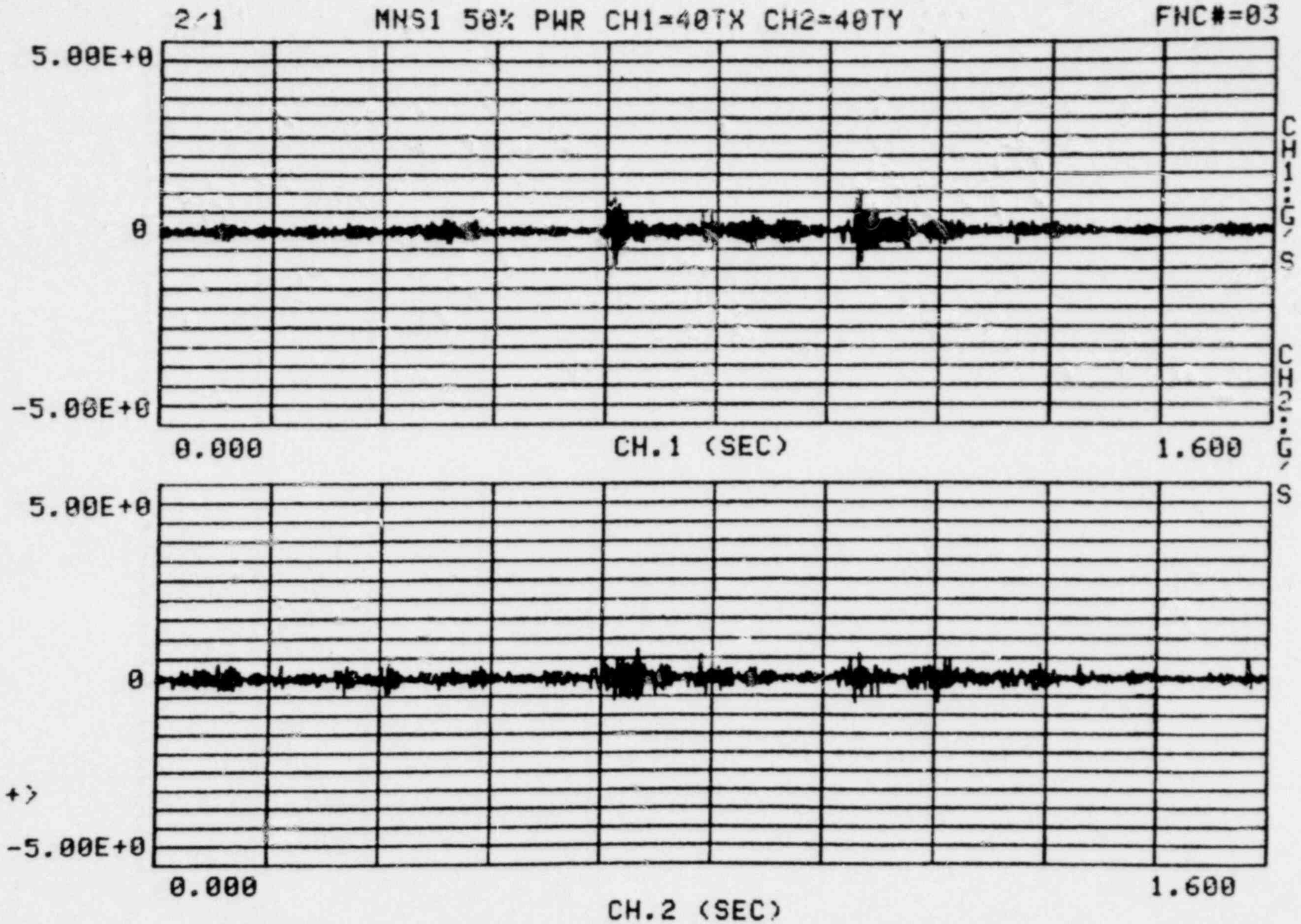

2/1
MNS1 50% PWR CH1=40TX CH2=40TY
FNC#=03
5.00E+0
0
-5.00E+0
0.000
CH.1 (SEC)
1.600
CH1:G/S
CH2:G/S
5.00E+0
0
-5.00E+0
0.000
1.600
CH.2 (SEC)

FIGURE 21

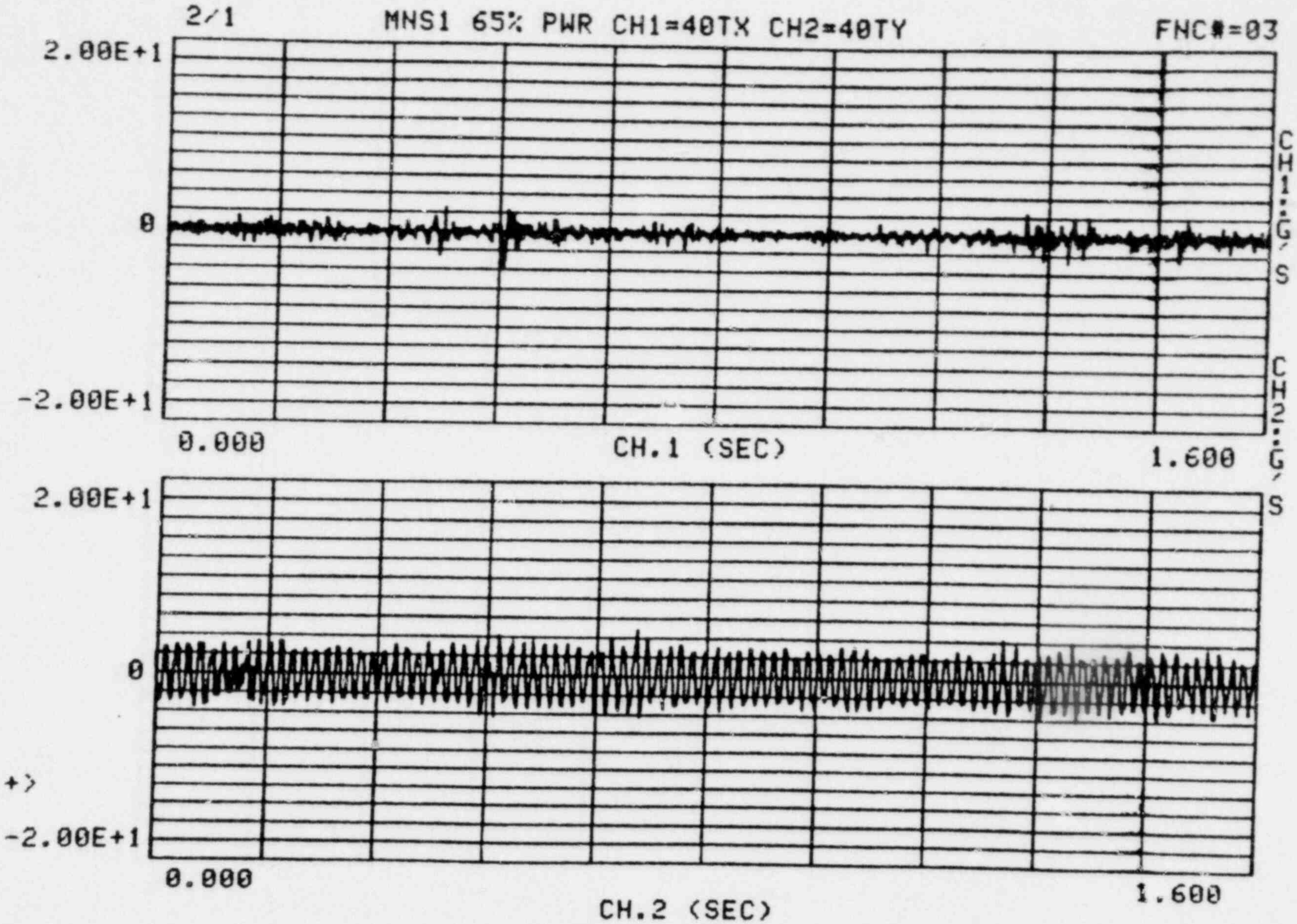

2/1
MNS1 65% PWR CH1=40TX CH2=40TY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.1 (SEC)
1.600
CH1:G/S
CH2:G/S
2.00E+1
0
+>
-2.00E+1
0.000
1.600
CH.2 (SEC)

FIGURE 22

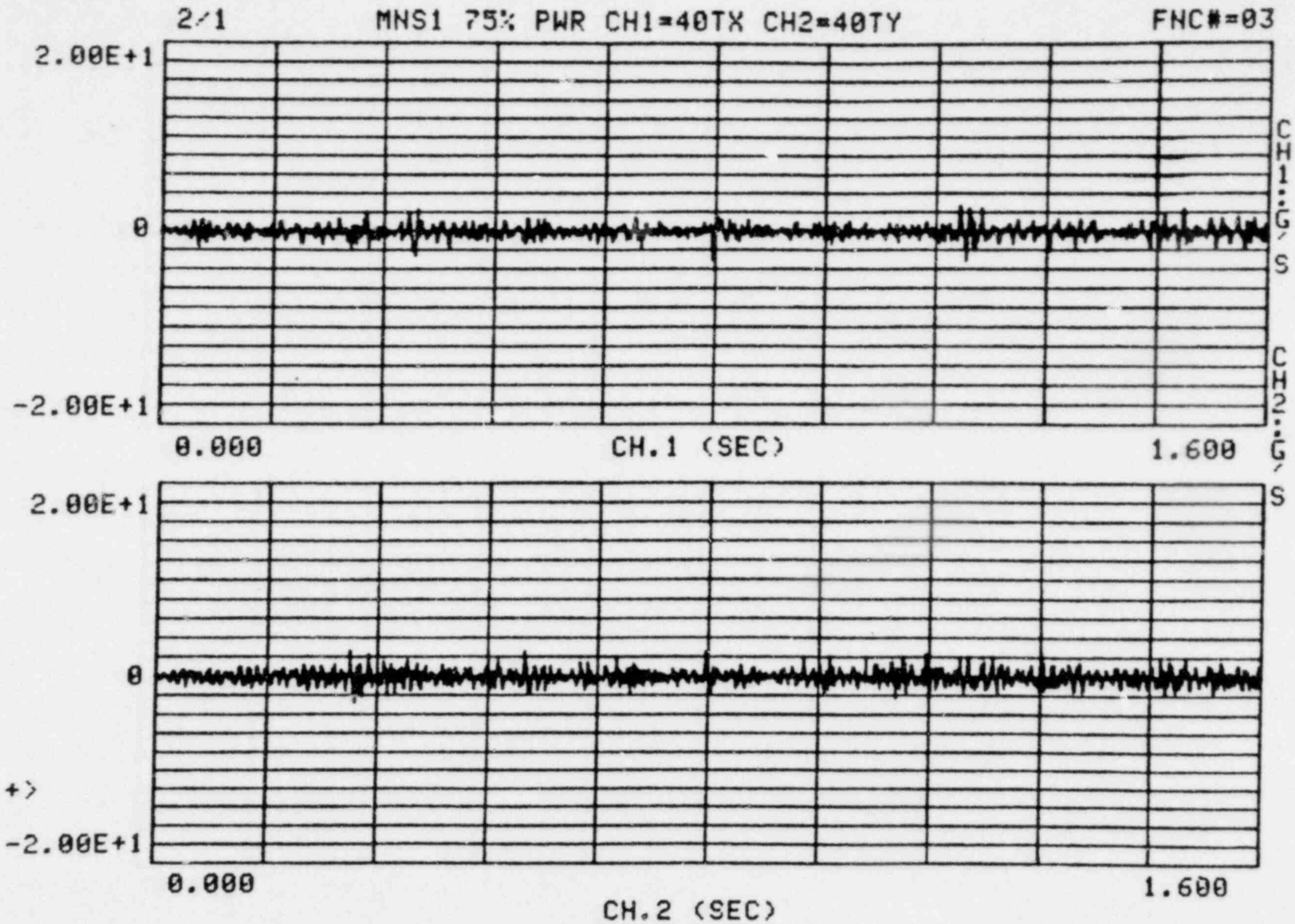

2/1
MNS1 75% PWR CH1=40TX CH2=40TY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.1 (SEC)
1.600
CH1:G/S
2.00E+1
0
+>
-2.00E+1
0.000
1.600
CH2:G/S
CH.2 (SEC)

FIGURE 23

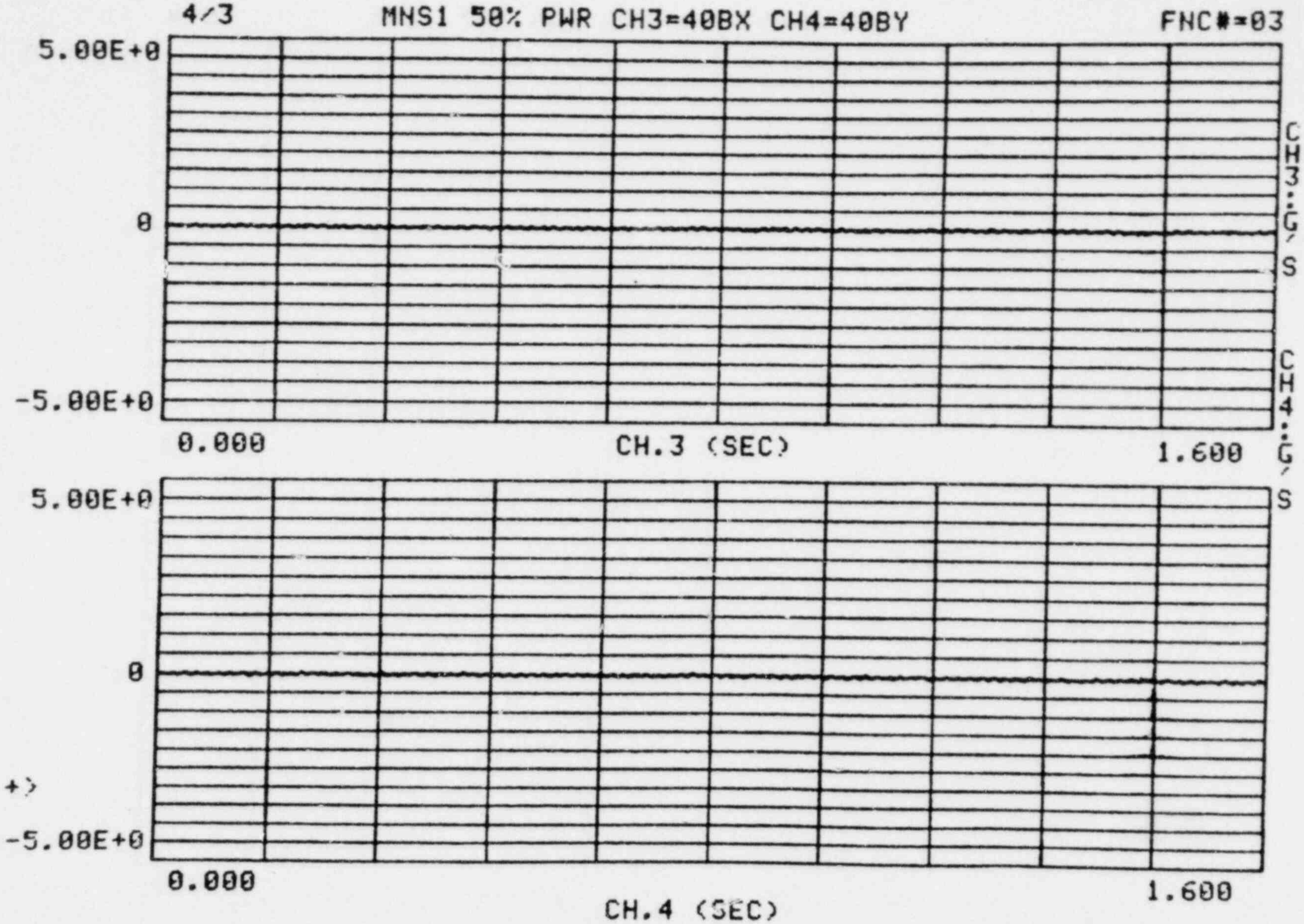
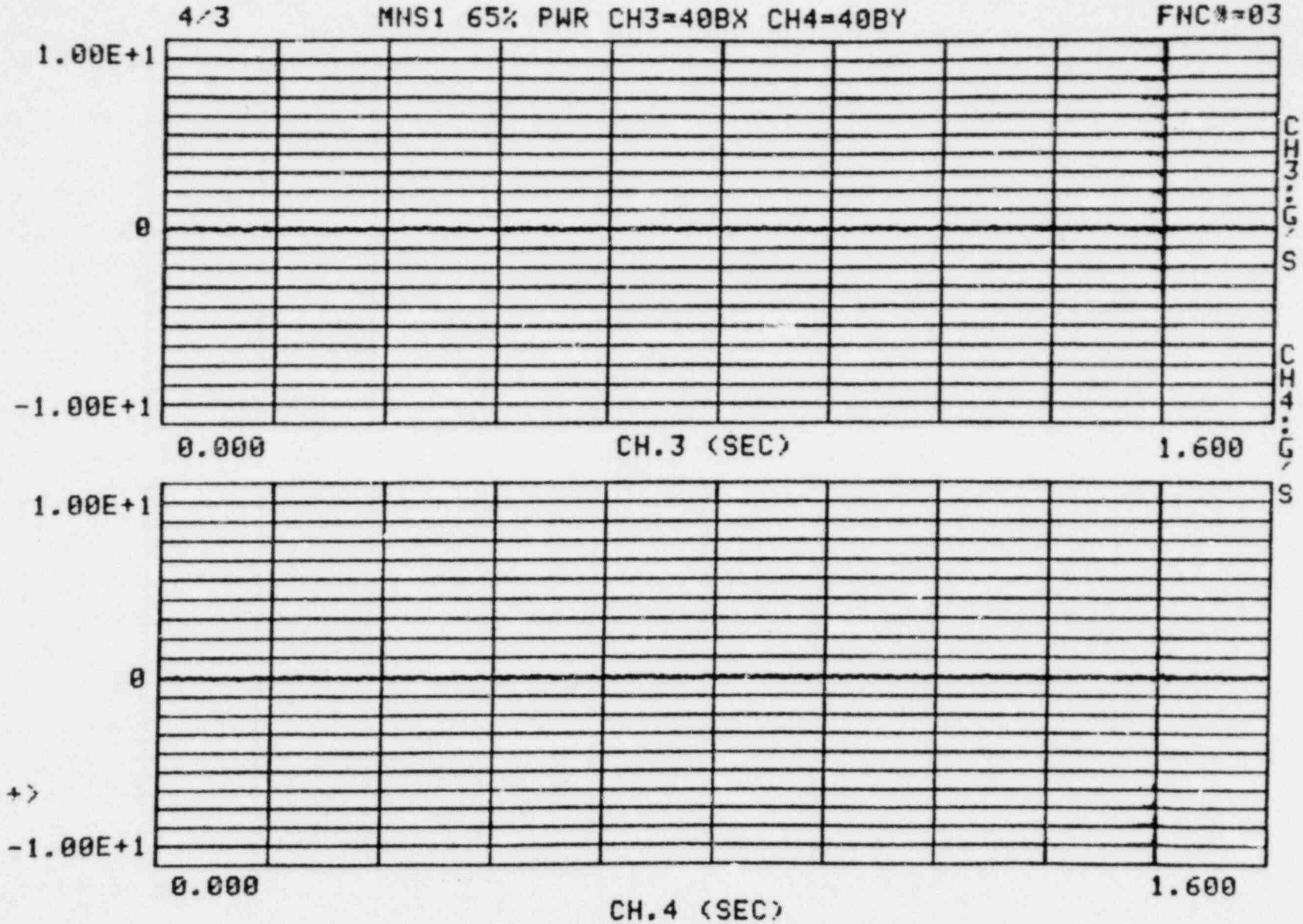

4/3
MNS1 50% PWR CH3=40BX CH4=40BY
FNC#=03
5.00E+0
0
-5.00E+0
0.000
CH.3 (SEC)
1.600
CH3:G'S
CH4:G'S
5.00E+0
0
-5.00E+0
0.000
CH.4 (SEC)
1.600

FIGURE 24



4/3
MNS1 65% PWR CH3=40BX CH4=40BY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.3 (SEC)
1.600
CH3:G/S
CH4:G/S
1.00E+1
0
+>
-1.00E+1
0.000
1.600
CH.4 (SEC)

FIGURE 25

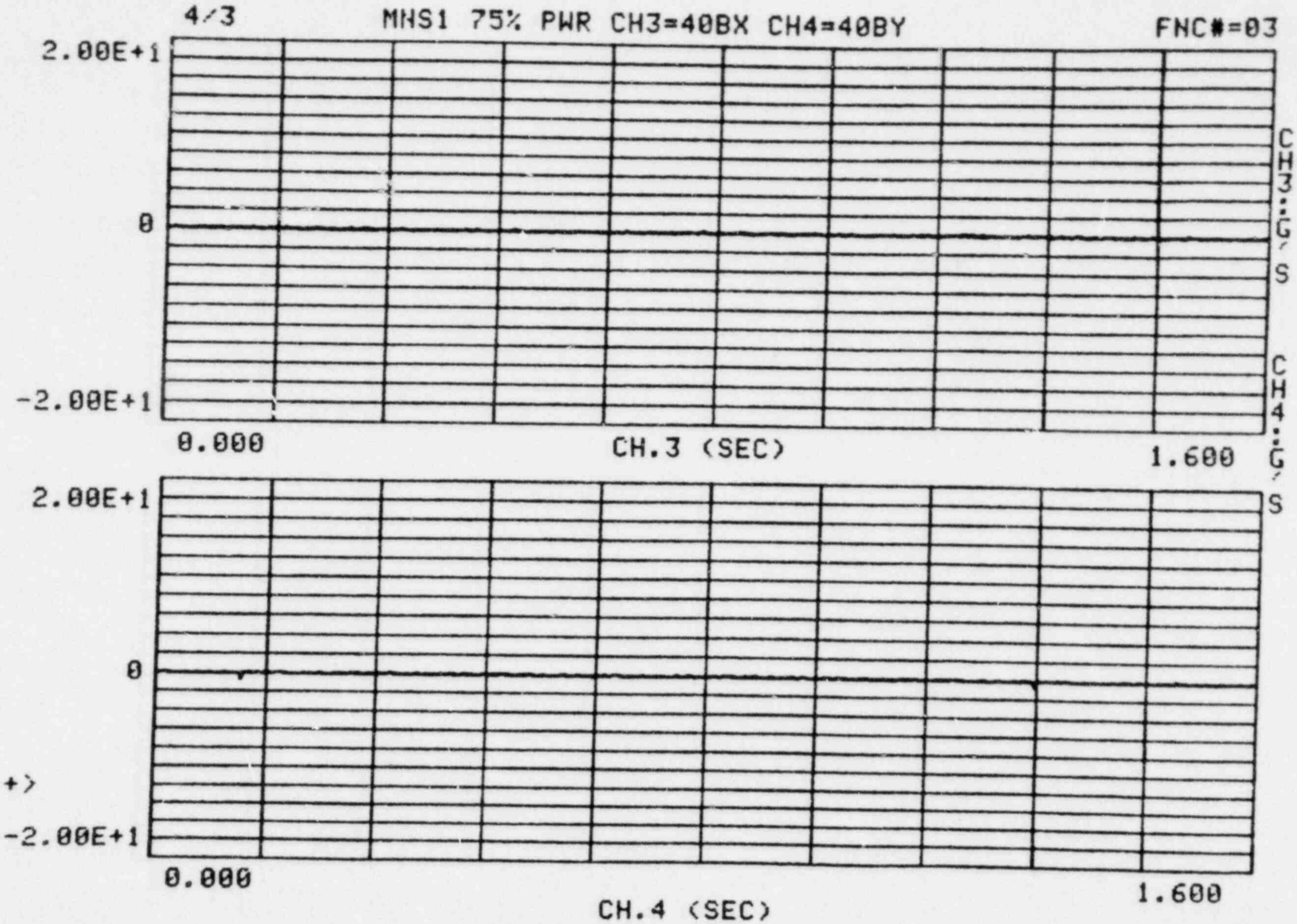
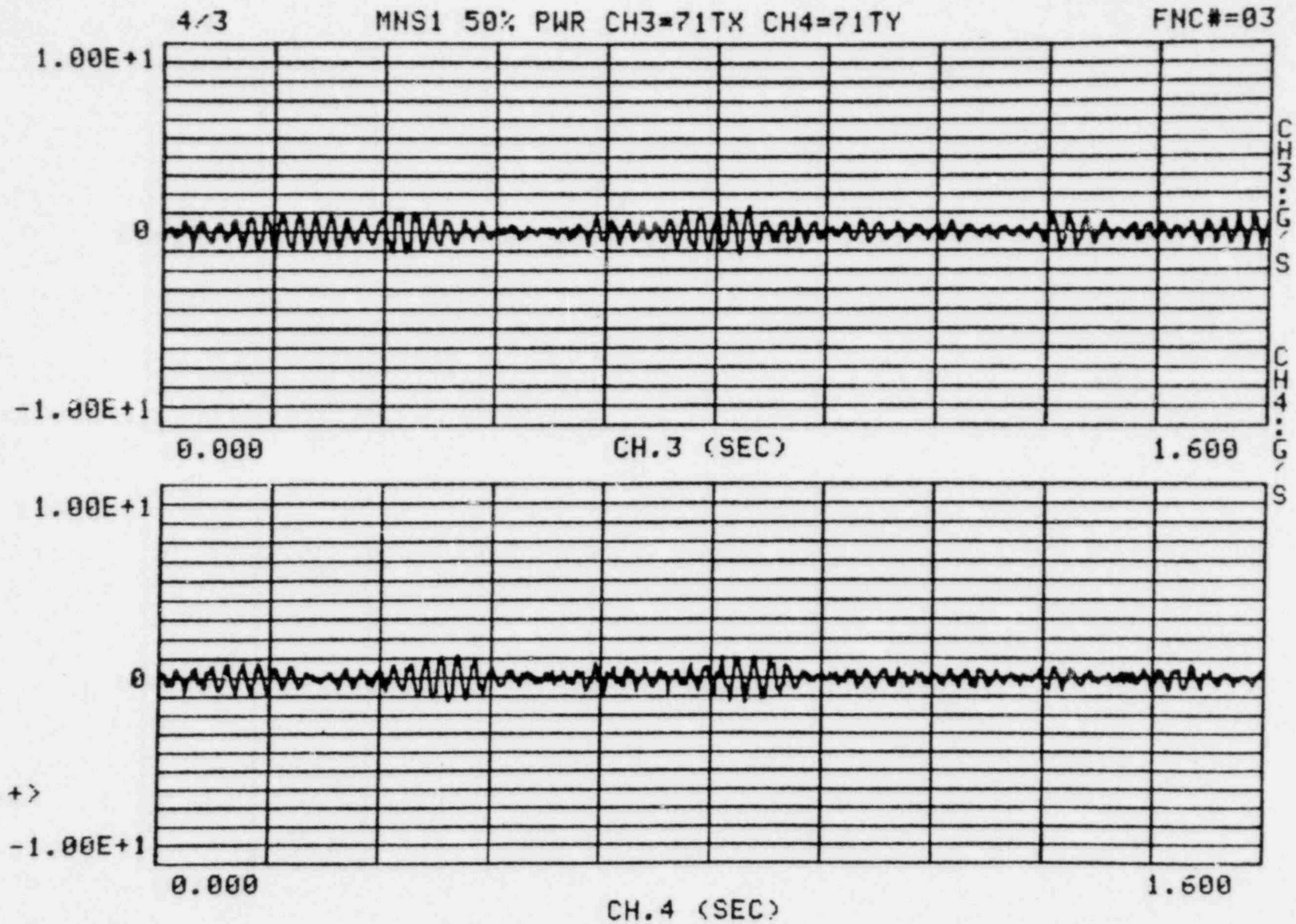
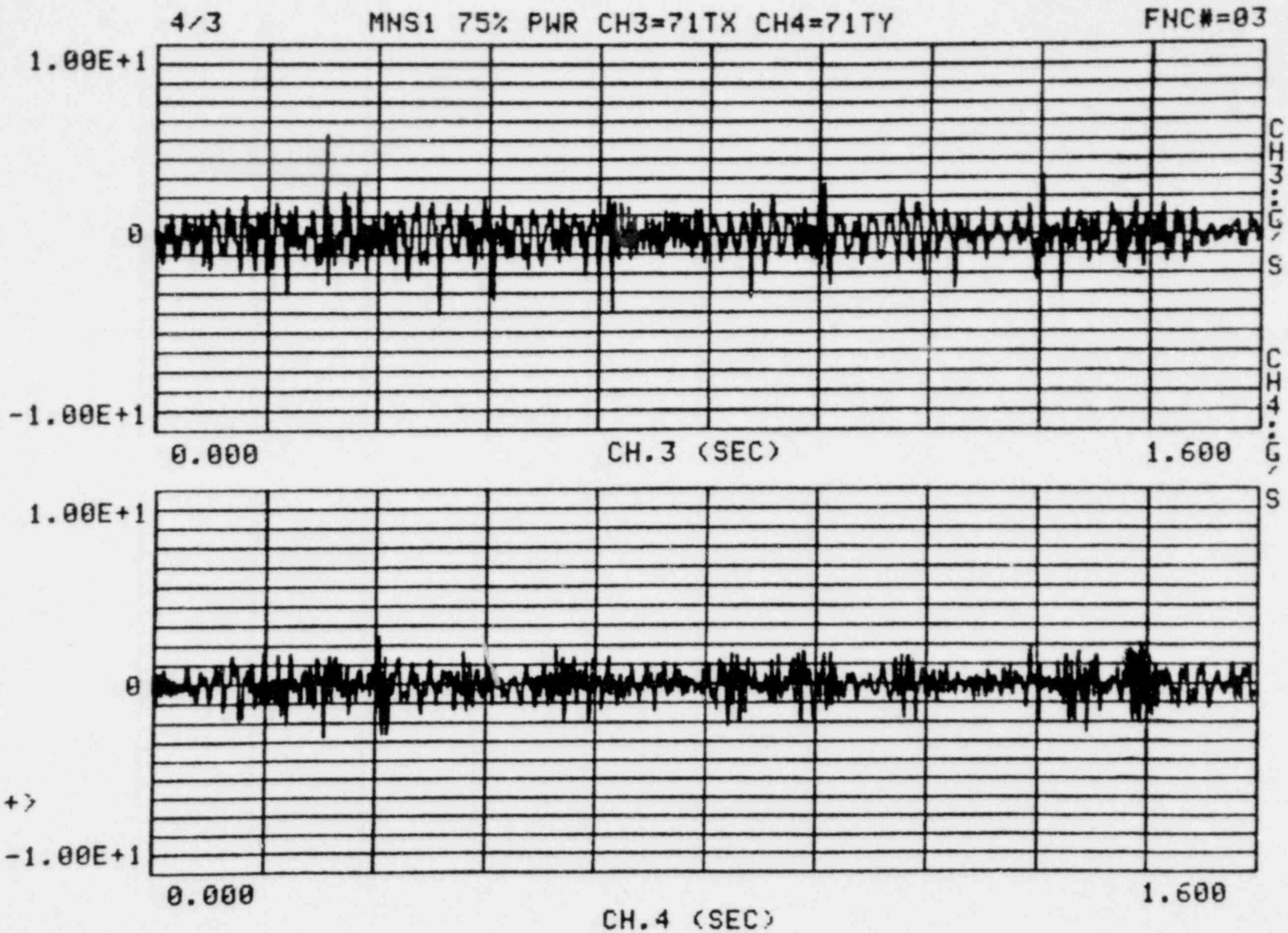

4/3
MHS1 75% PWR CH3=40BX CH4=40BY
FNC#=03
2.00E+1
0
-2.00E+1
0.000
CH.3 (SEC)
1.600
CH3:G/S
CH4:G/S
2.00E+1
0
+>
-2.00E+1
0.000
1.600
CH.4 (SEC)

FIGURE 26



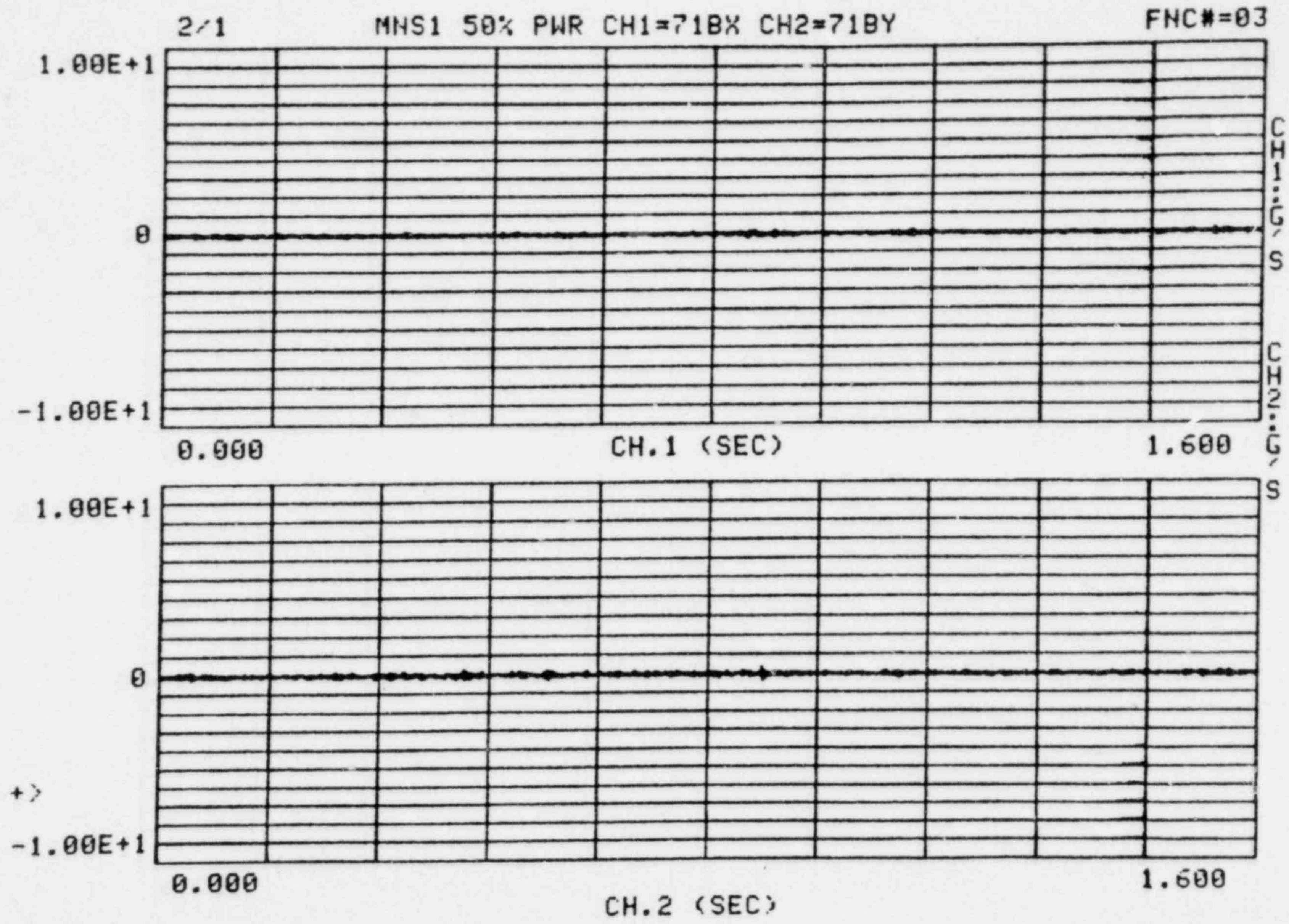
4/3
MNS1 50% PWR CH3=71TX CH4=71TY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.3 (SEC)
1.600
CH3:G/S
CH4:G/S
1.00E+1
0
+>
-1.00E+1
0.000
1.600
CH.4 (SEC)

FIGURE 27



4/3
MNS1 75% PWR CH3=71TX CH4=71TY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.3 (SEC)
1.600
CH3:G/S
CH4:G/S
1.00E+1
0
-1.00E+1
0.000
1.600
CH.4 (SEC)

FIGURE 28



2/1
MNS1 50% PWR CH1=71BX CH2=71BY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.1 (SEC)
1.600
CH1:G/S
CH2:G/S
1.00E+1
0
+>
-1.00E+1
0.000
1.600
CH.2 (SEC)

FIGURE 29

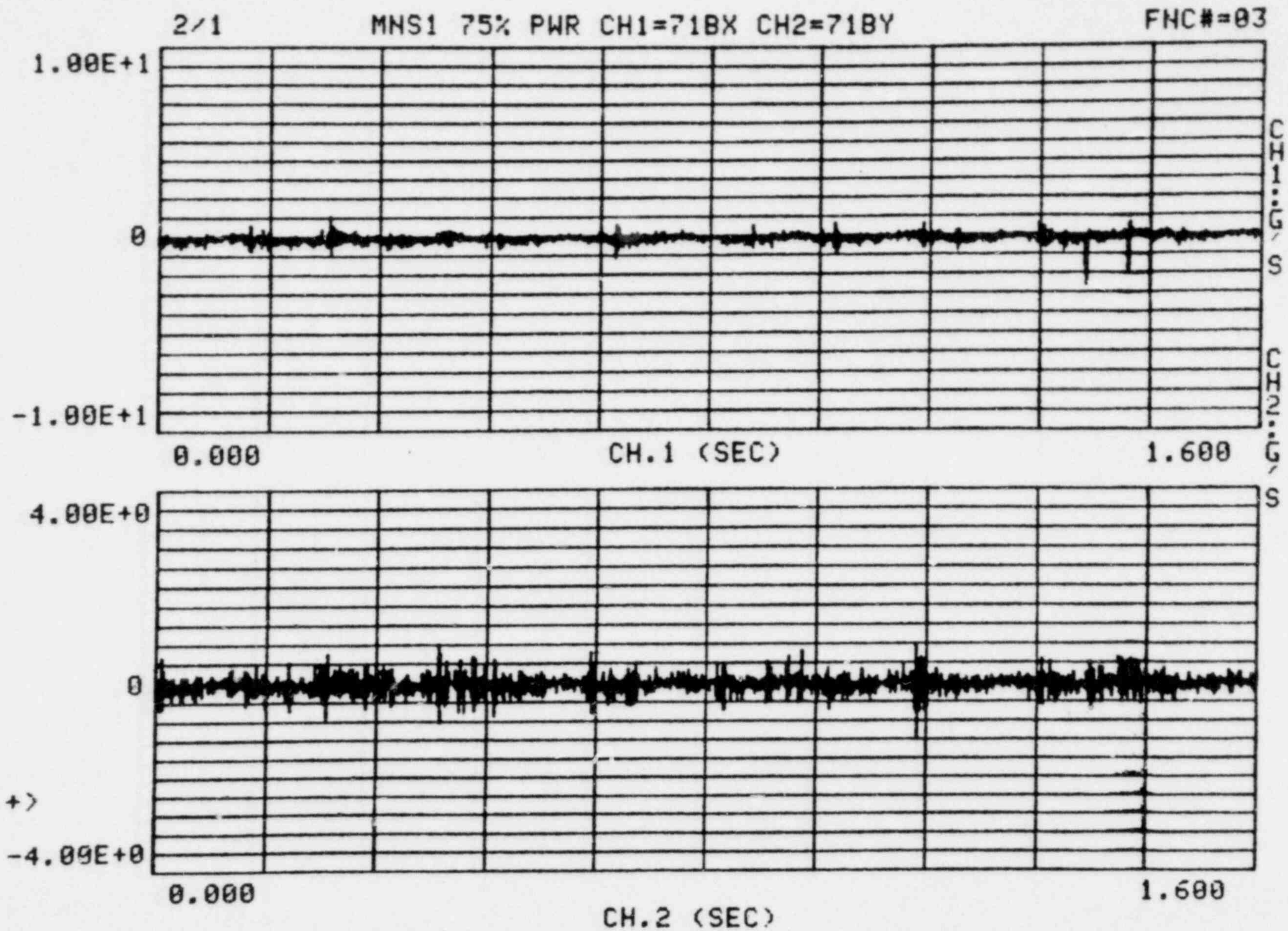
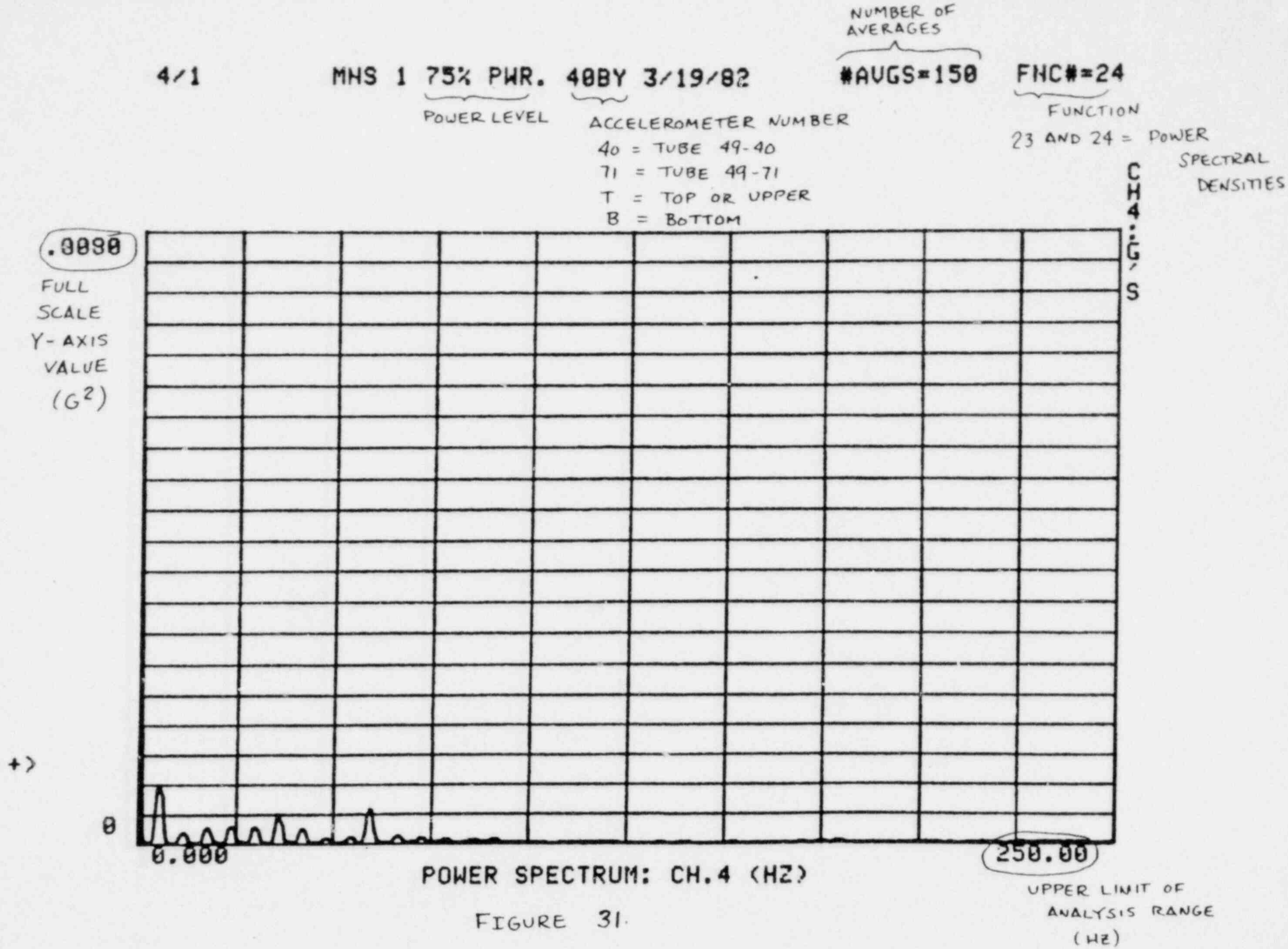

2/1
MNS1 75% PWR CH1=71BX CH2=71BY
FNC#=03
1.00E+1
0
-1.00E+1
0.000
CH.1 (SEC)
1.600
CH1:G/S
CH2:G/S
4.00E+0
0
+>
-4.09E+0
0.000
1.600
CH.2 (SEC)

FIGURE 30



4/1
MHS 1 75% PWR. 40BY 3/19/82
NUMBER OF AVERAGES
#AVGS=150
FNC#=24
POWER LEVEL
ACCELEROMETER NUMBER
40 = TUBE 49-40
71 = TUBE 49-71
T = TOP OR UPPER
B = BOTTOM
FUNCTION
23 AND 24 = POWER SPECTRAL DENSITIES
CH4:G/S
.0090
FULL SCALE Y-AXIS VALUE (G^2)
+>
0
0.000
250.00
POWER SPECTRUM: CH.4 (HZ)
UPPER LIMIT OF ANALYSIS RANGE (HZ)

FIGURE 31

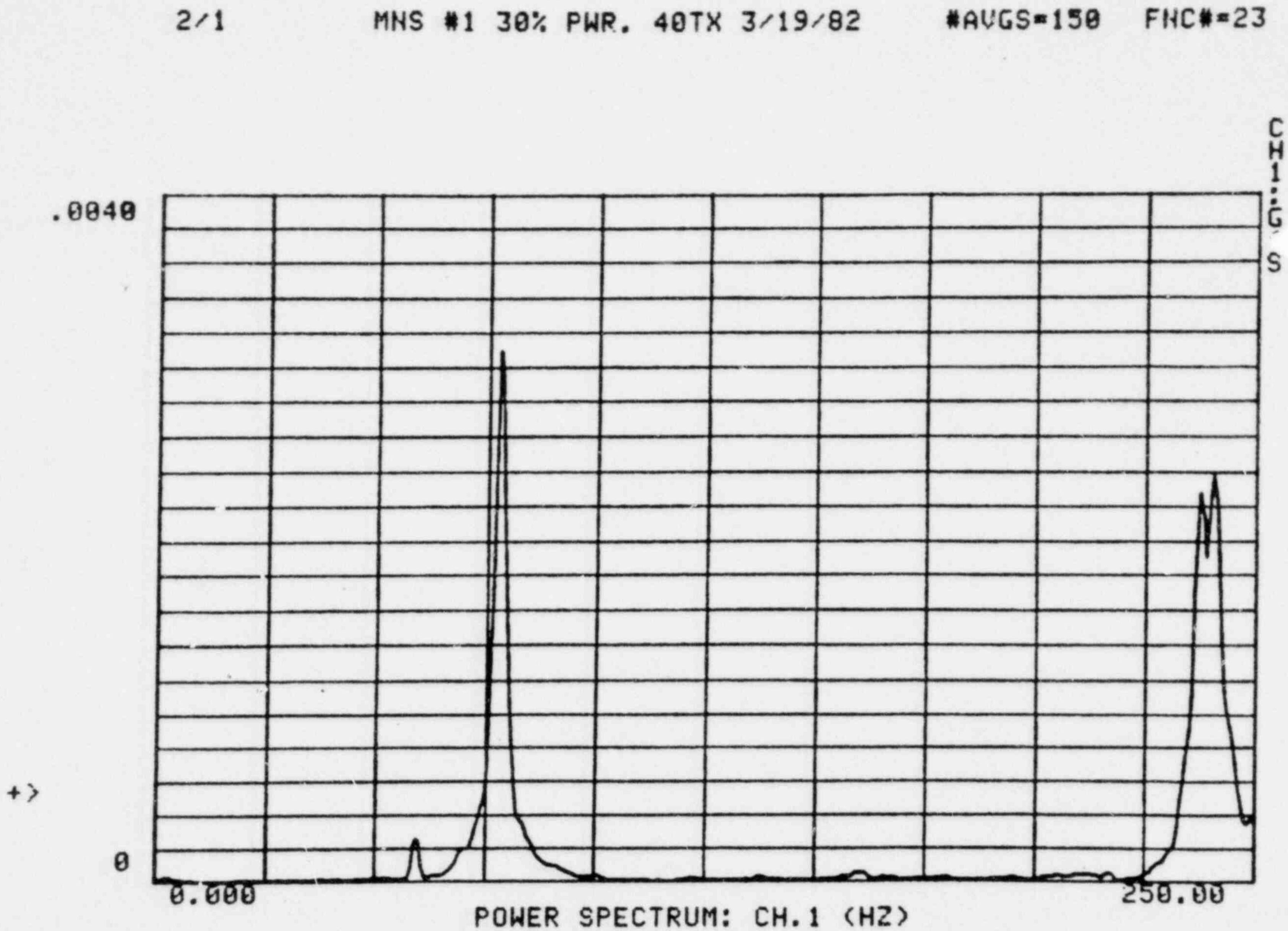
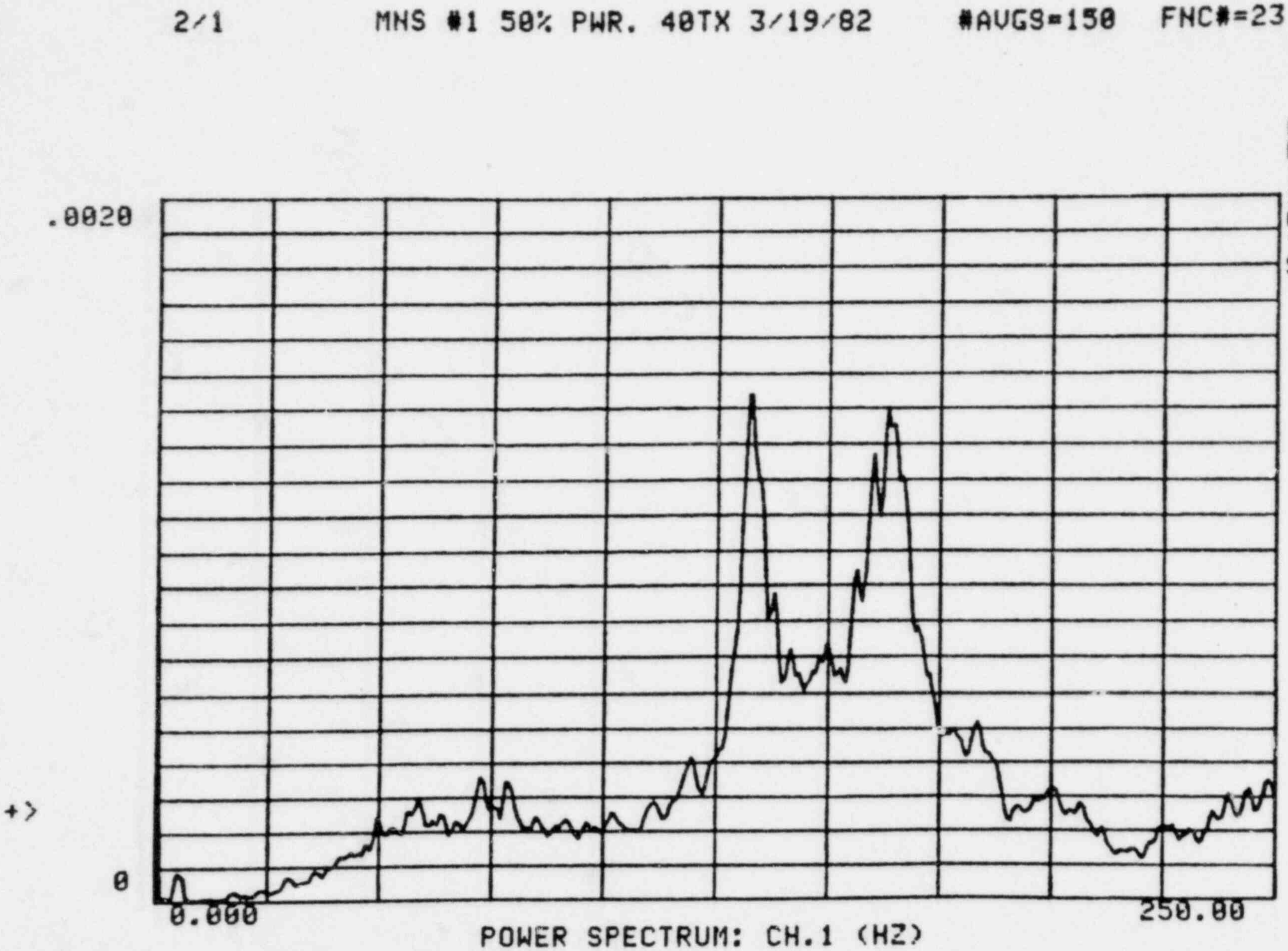

2/1
MNS #1 30% PWR. 40TX 3/19/82
#AVGS=150
FNC#=23
CH1:GS
.0040
+>
0
0.000
250.00
POWER SPECTRUM: CH.1 (HZ)

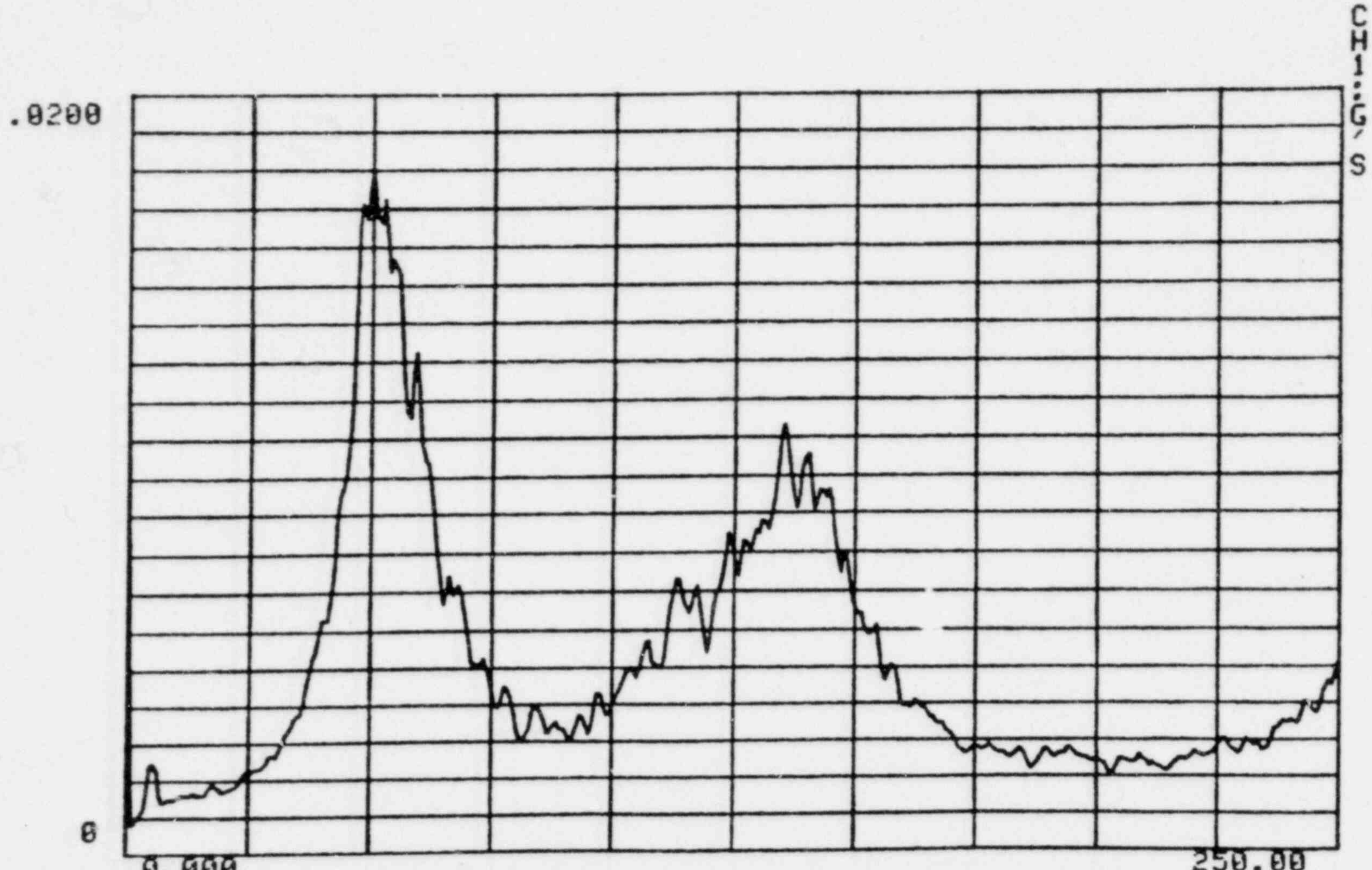
FIGURE 32



2/1
MNS #1 50% PWR. 40TX 3/19/82
#AVGS=150
FNC#=23
CH1:G/S
.0020
+>
0
0.000
250.00
POWER SPECTRUM: CH.1 (HZ)

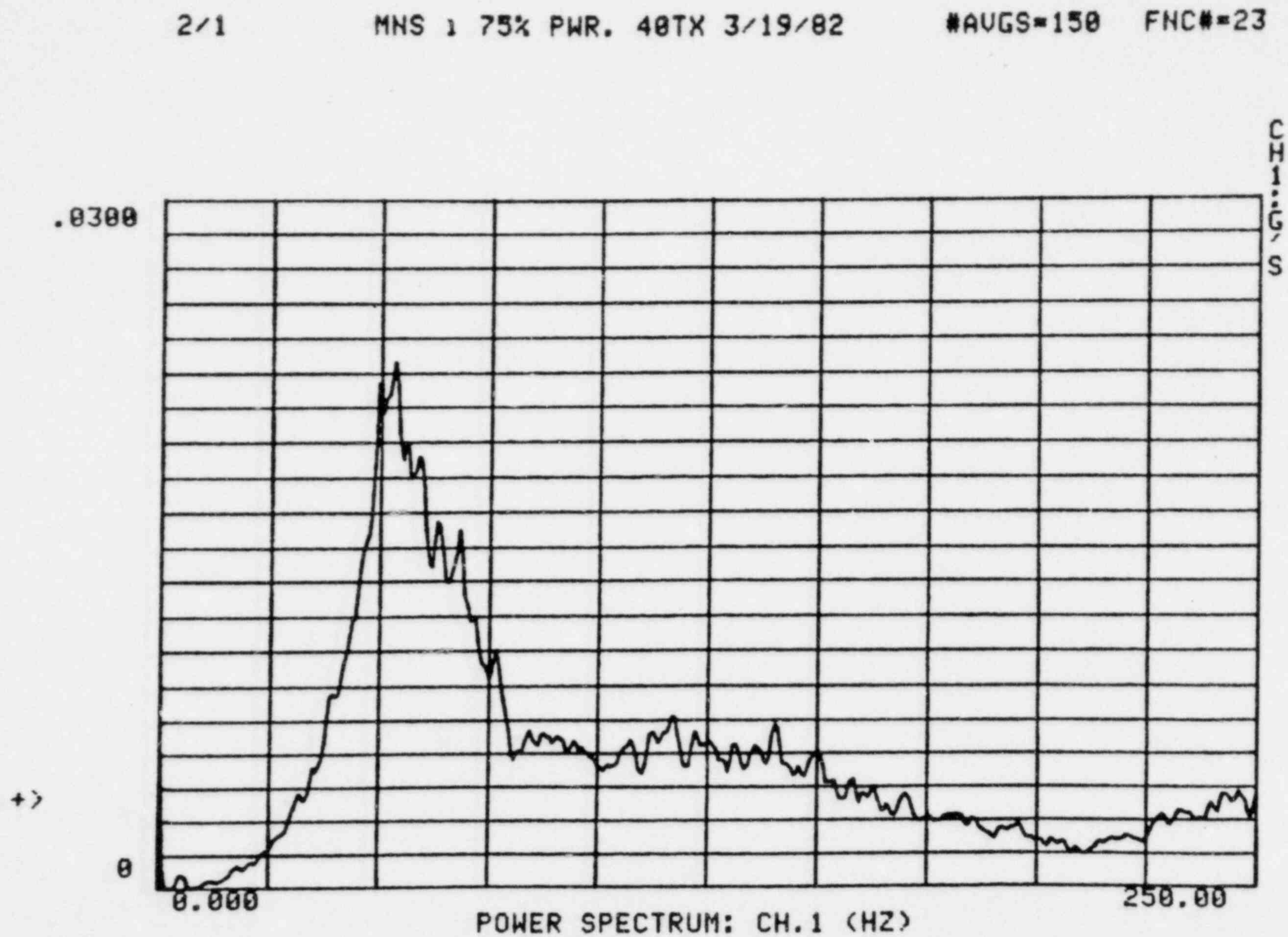
FIGURE 33

2/1 MNS #1 65% PWR. 40TX 3/19/82 #AVGS=150 FNC#=23



POWER SPECTRUM: CH.1 (HZ)

FIGURE 34



2/1
MNS 1 75% PWR. 40TX 3/19/82
#AVGS=150
FNC#=23
CH1:G/S
.0300
+>
0
0.000
250.00
POWER SPECTRUM: CH.1 (HZ)

FIGURE 35

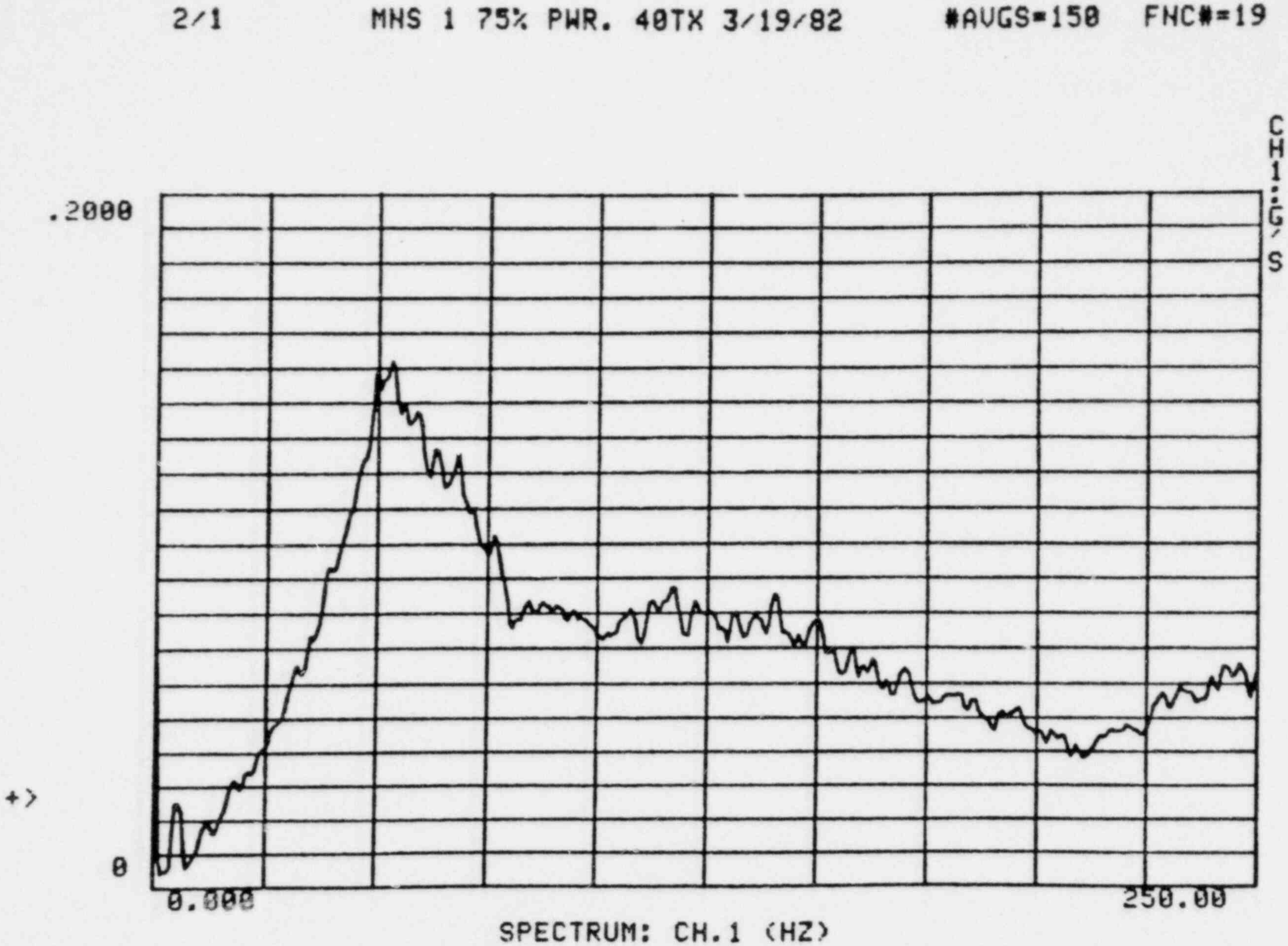
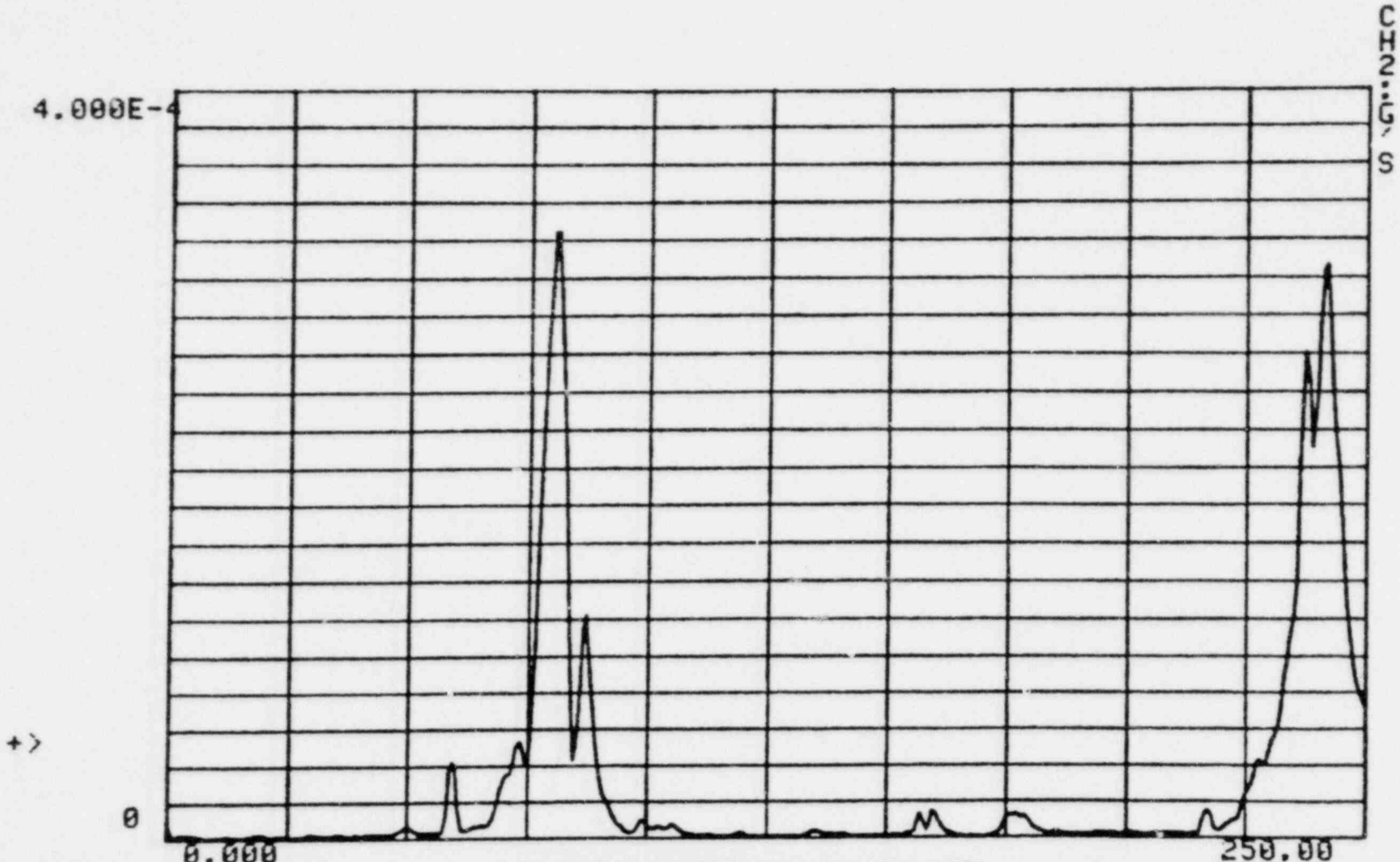

2/1
MHS 1 75% PWR. 40TX 3/19/82
#AVGS=150
FNC#=19
CH1:G/S
.2000
+>
0
0.000
250.00
SPECTRUM: CH.1 (HZ)

FIGURE 36

2/1 MHS #1 30% PWR. 40TY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.2 (HZ)

FIGURE 37

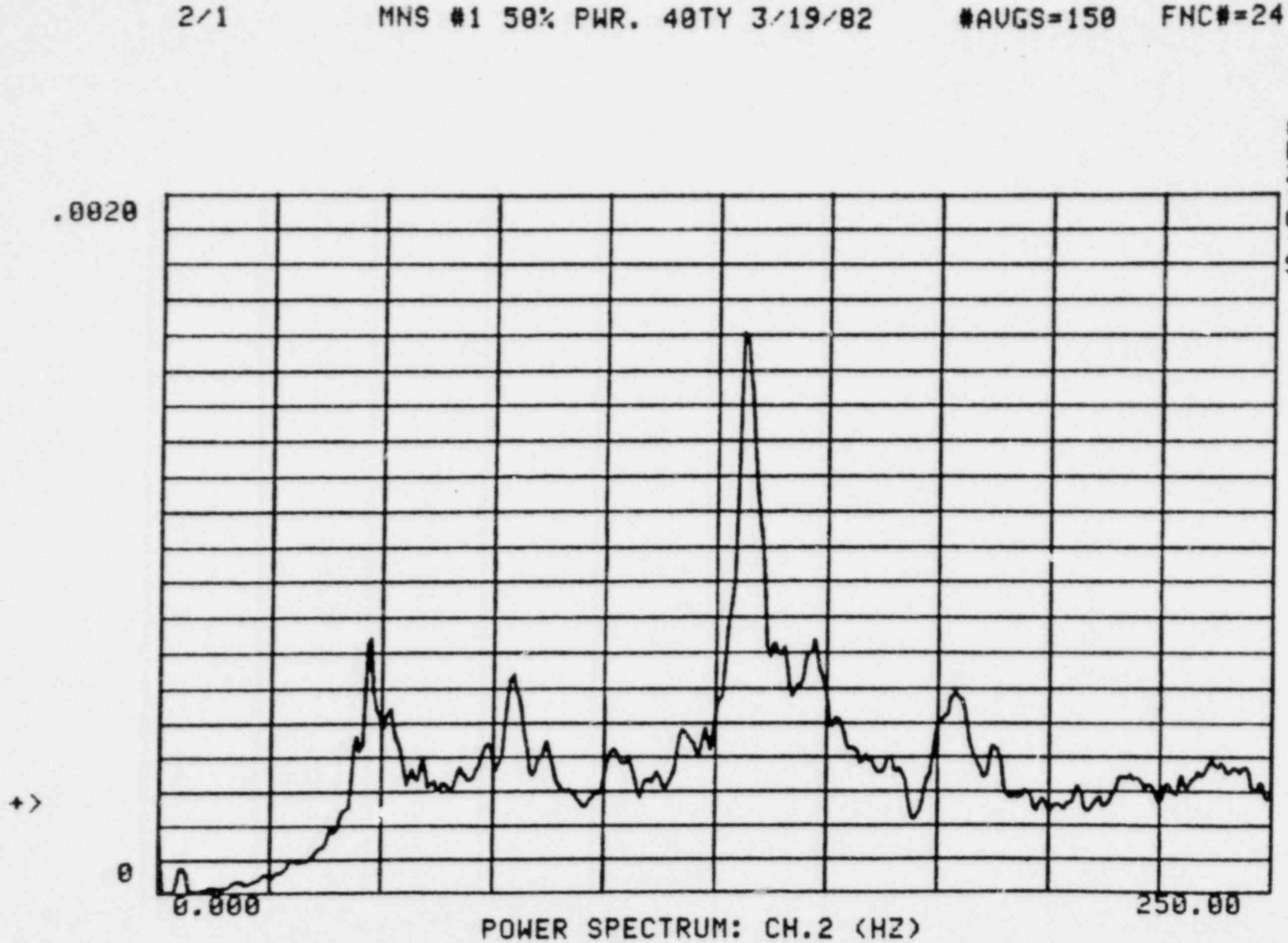
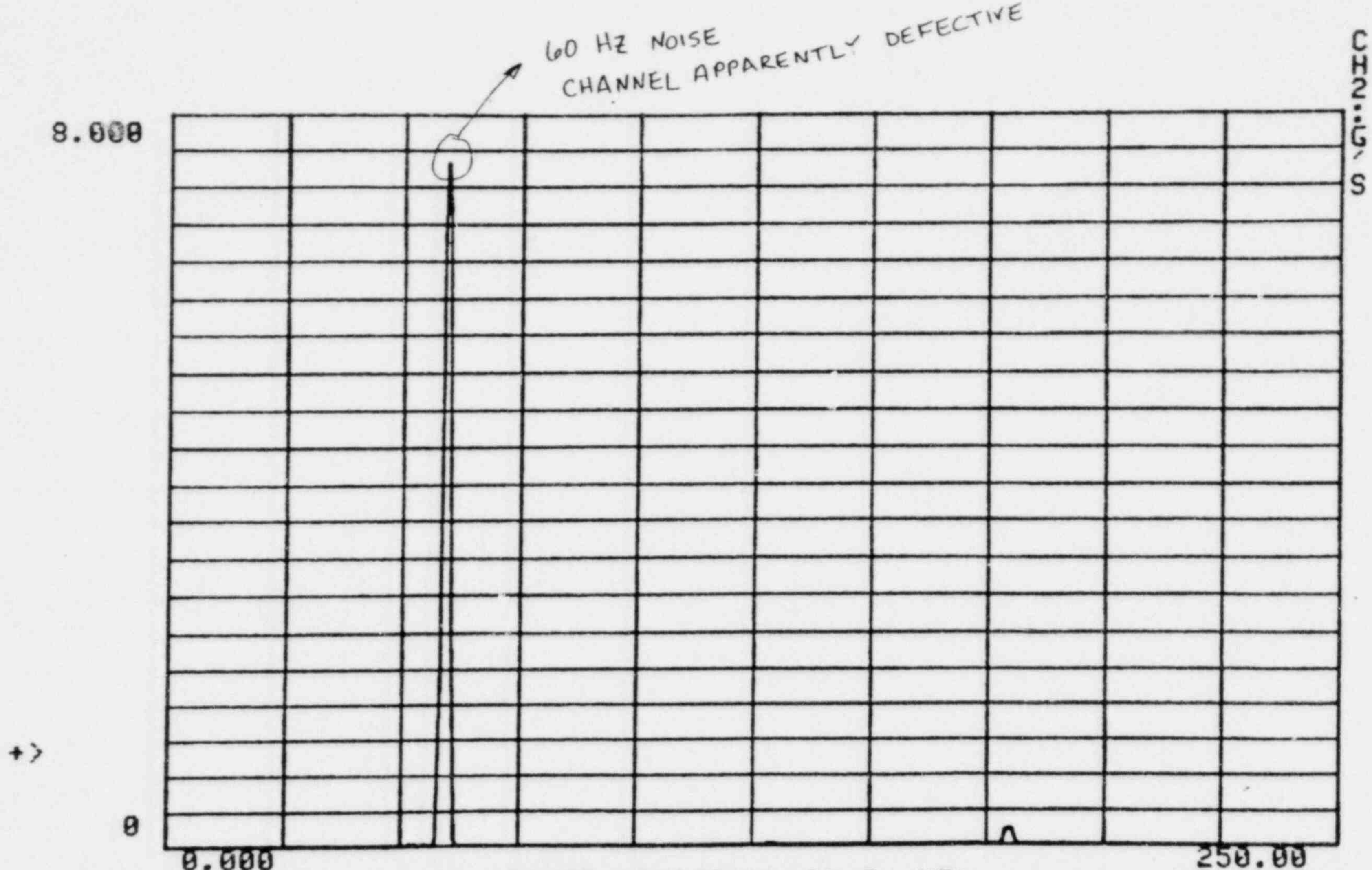

2/1
MNS #1 50% PWR. 40TY 3/19/82
#AVGS=150
FNC#=24
CH2:G/S
.0020
+>
0
0.000
250.00
POWER SPECTRUM: CH.2 (HZ)

FIGURE 38

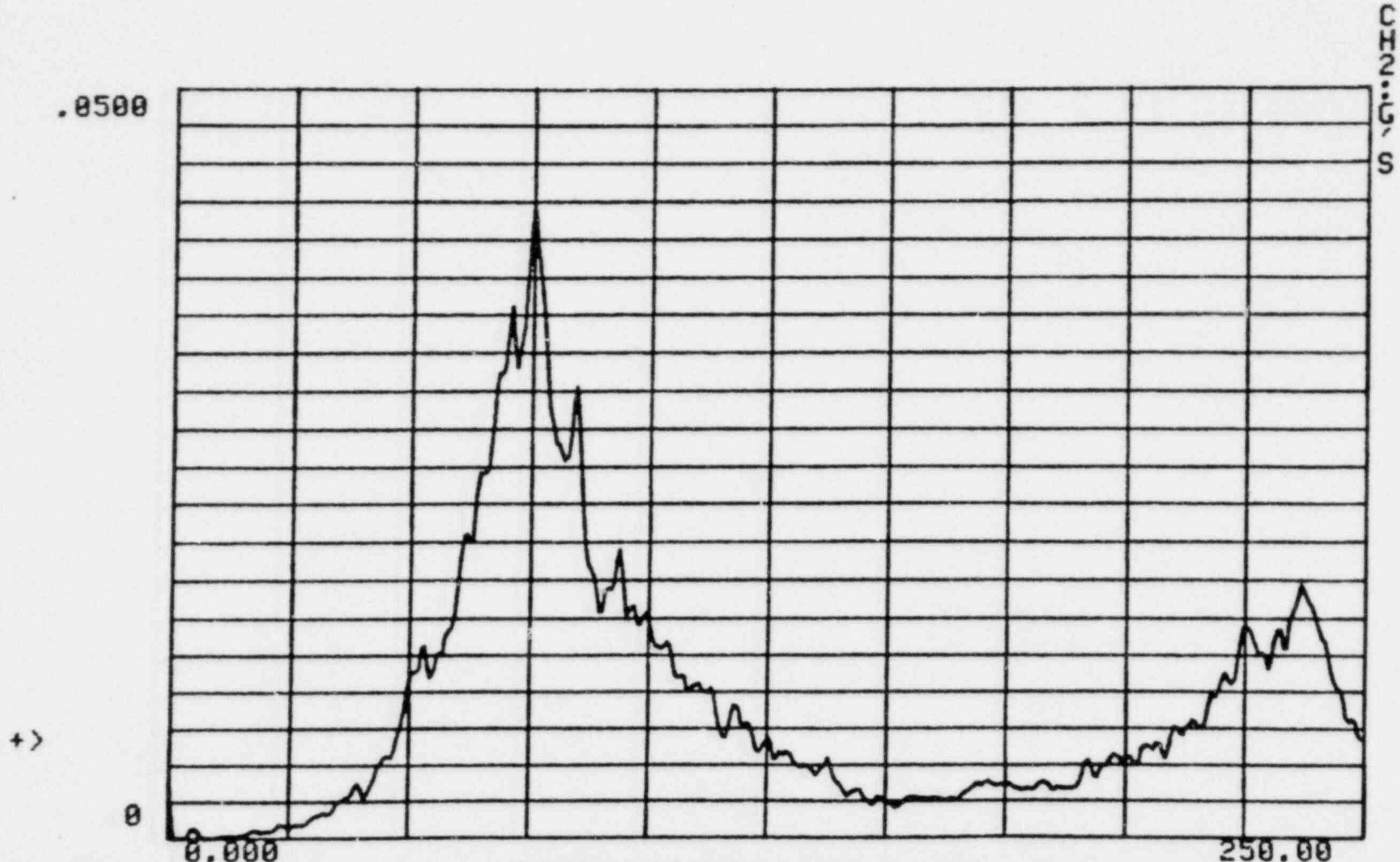
2/1 MNS #1 65% PWR. 40TY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.2 (HZ)

FIGURE 39

2/1 MNS 1 75% PWR. 40TY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.2 (HZ)

FIGURE 4D

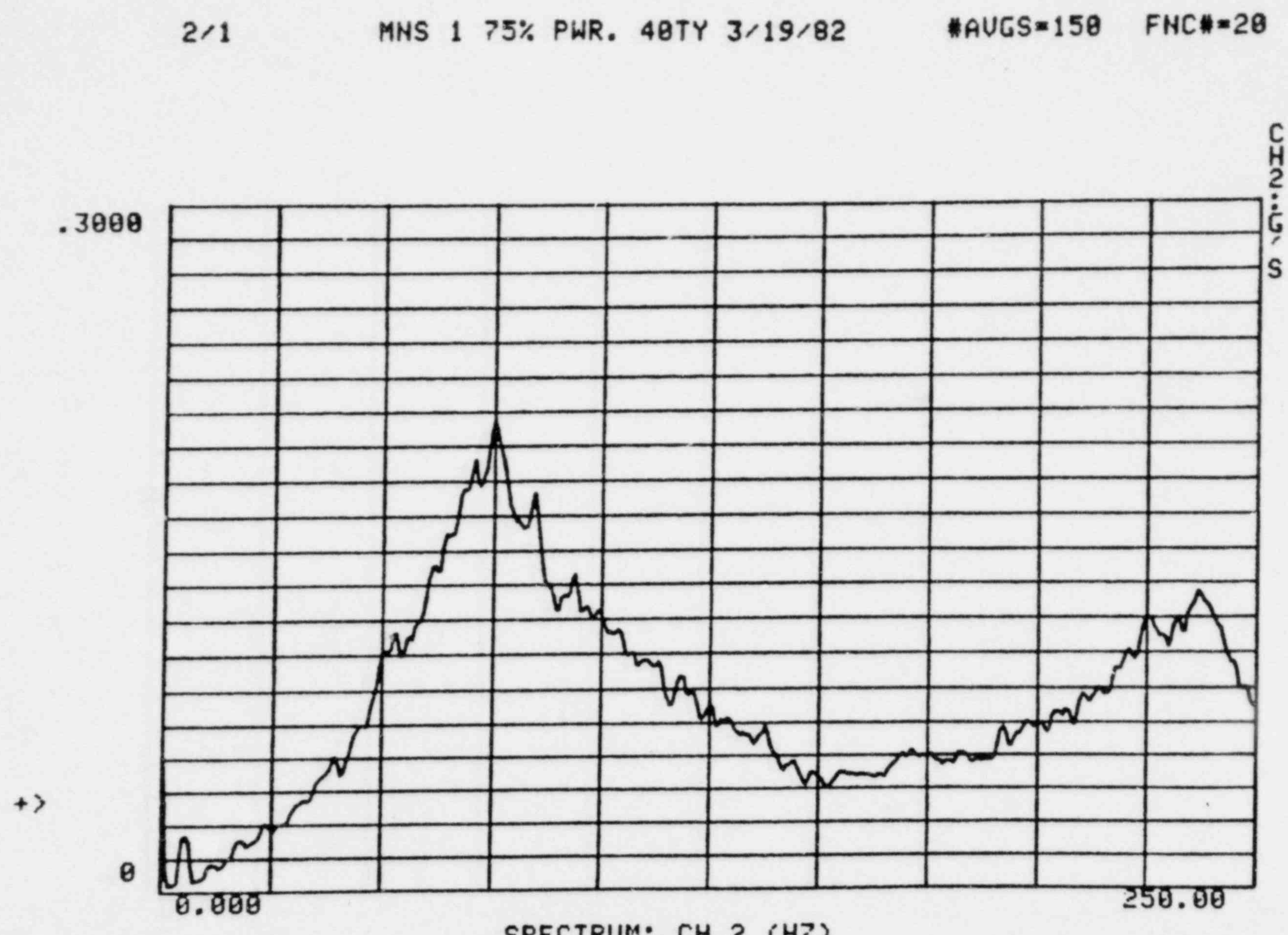

2/1
MNS 1 75% PWR. 40TY 3/19/82
#AVGS=150
FNC#=20
CH2:G/S
.3000
+>
0
0.000
250.00
SPECTRUM: CH.2 (HZ)

FIGURE 41

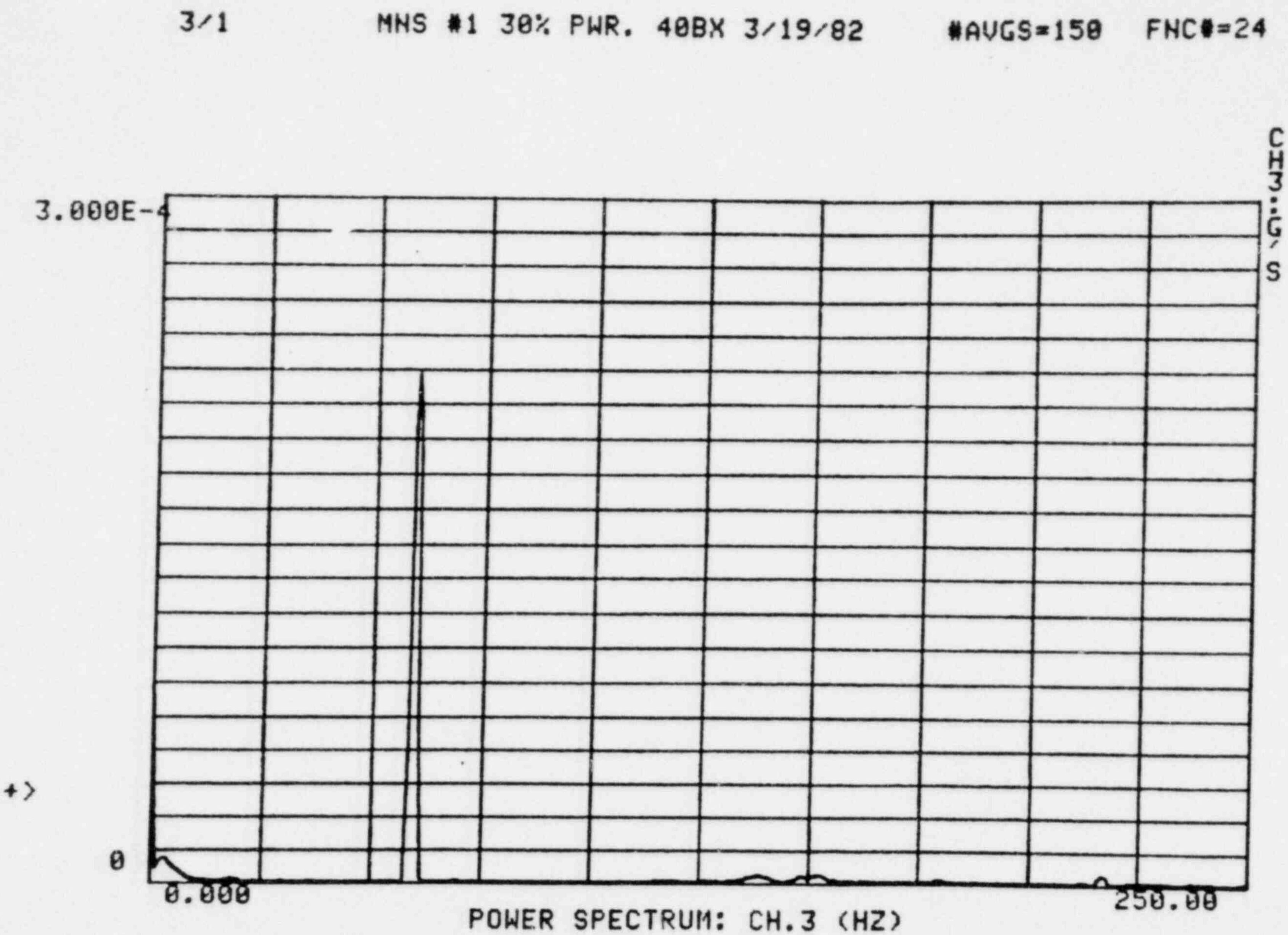

3/1
MNS #1 30% PWR. 40BX 3/19/82
#AVGS=150
FNC#=24
CH3:G/S
3.000E-4
+>
0
0.000
250.00
POWER SPECTRUM: CH.3 (HZ)

FIGURE 42

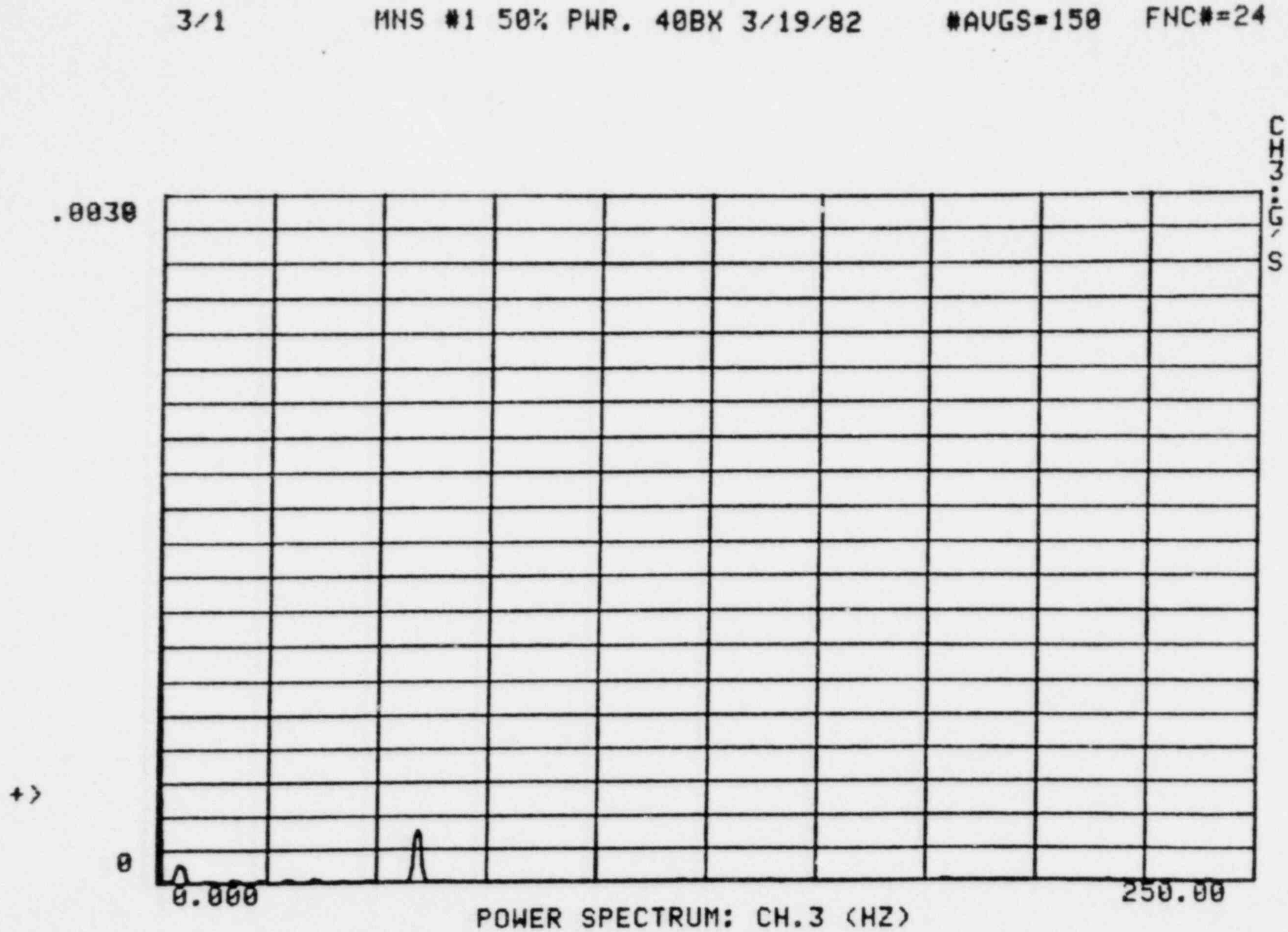

3/1
MNS #1 50% PWR. 40BX 3/19/82
#AVGS=150
FNC#=24
CH3:G/S
.0030
+>
0
0.000
250.00
POWER SPECTRUM: CH.3 (HZ)

FIGURE 43

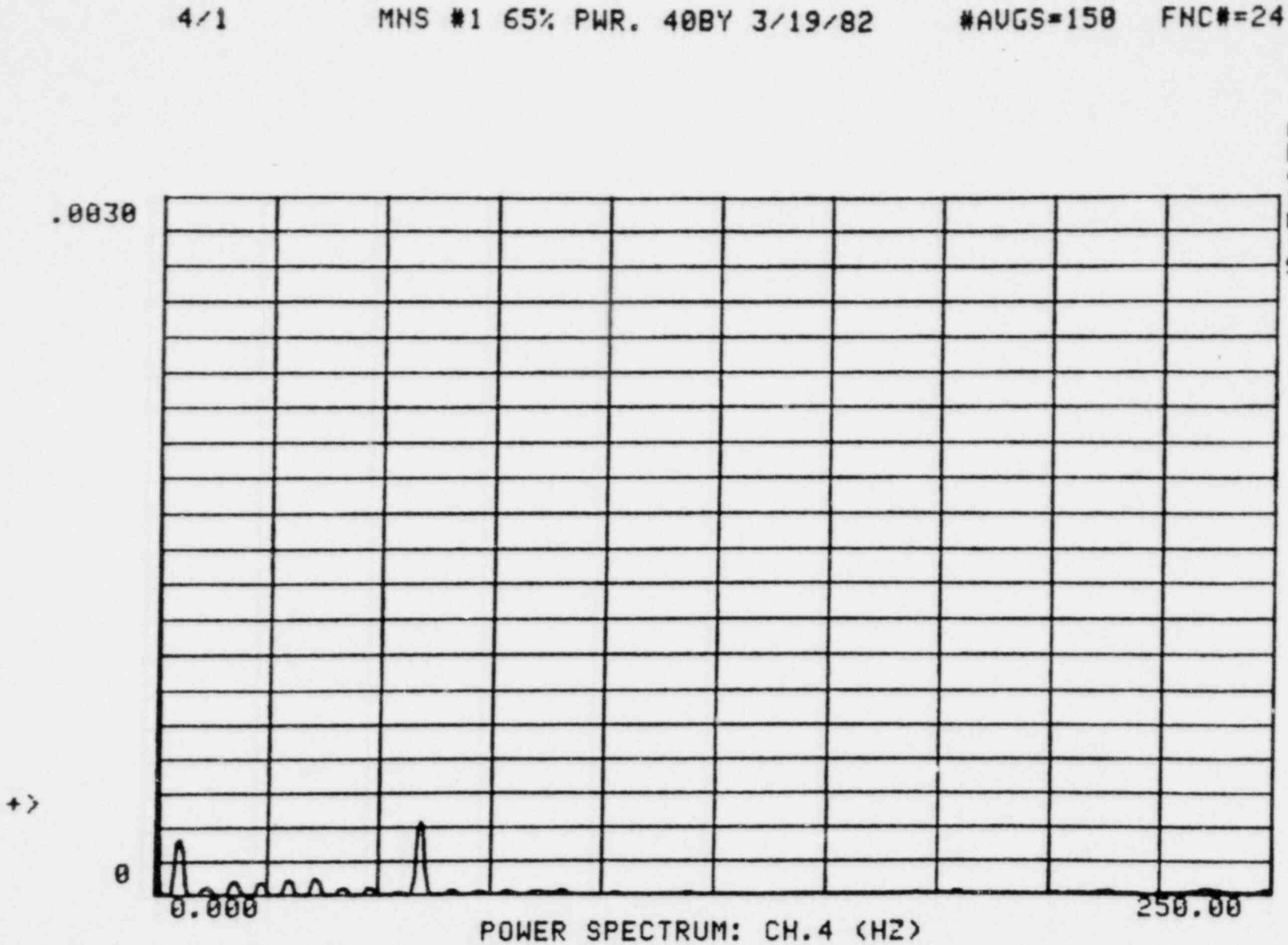

4/1
MNS #1 65% PWR. 40BY 3/19/82
#AVGS=150
FNC#=24
CH4:G/S
.0030
0
+>
0.000
250.00
POWER SPECTRUM: CH.4 (HZ)

FIGURE 44

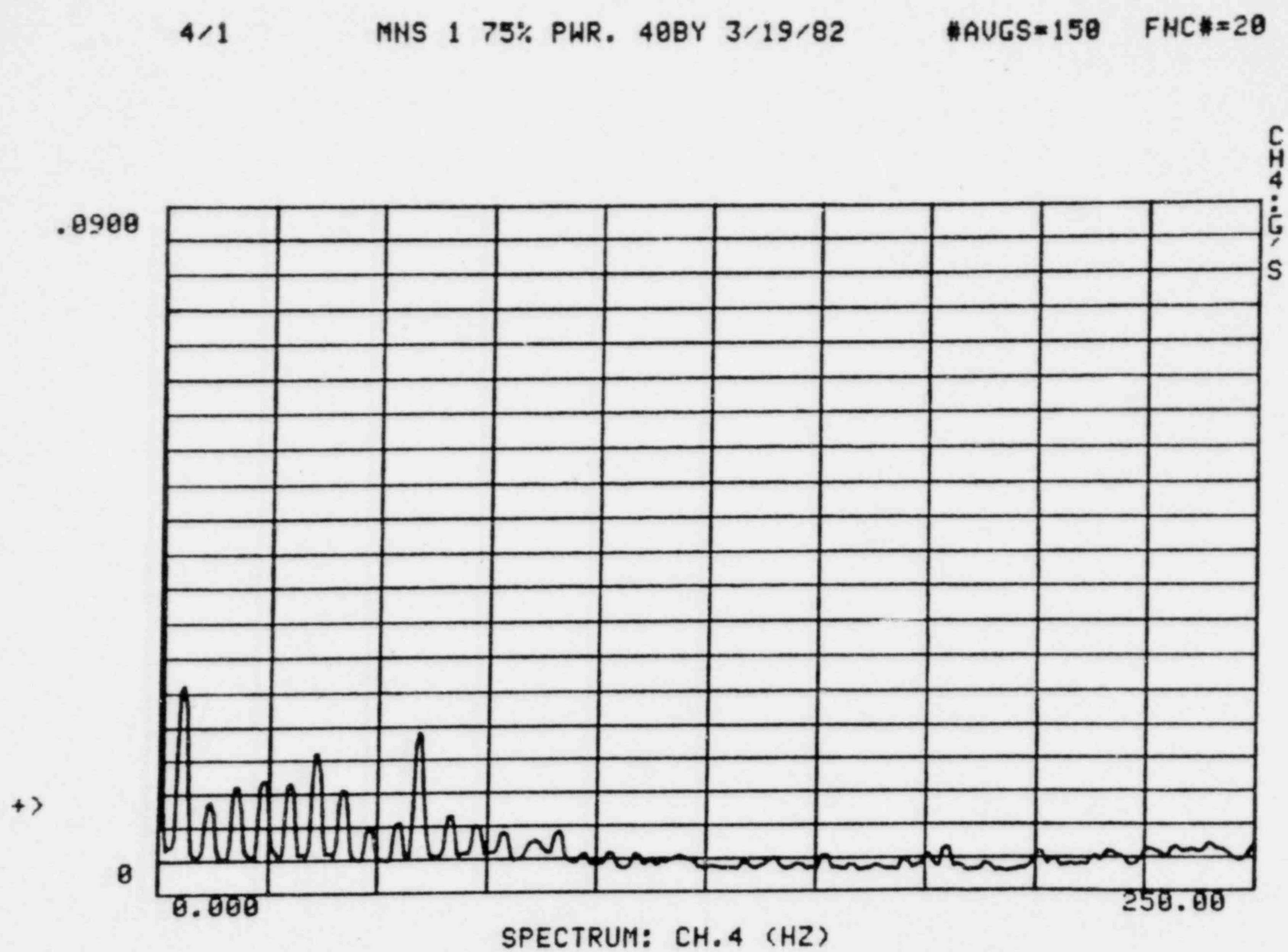
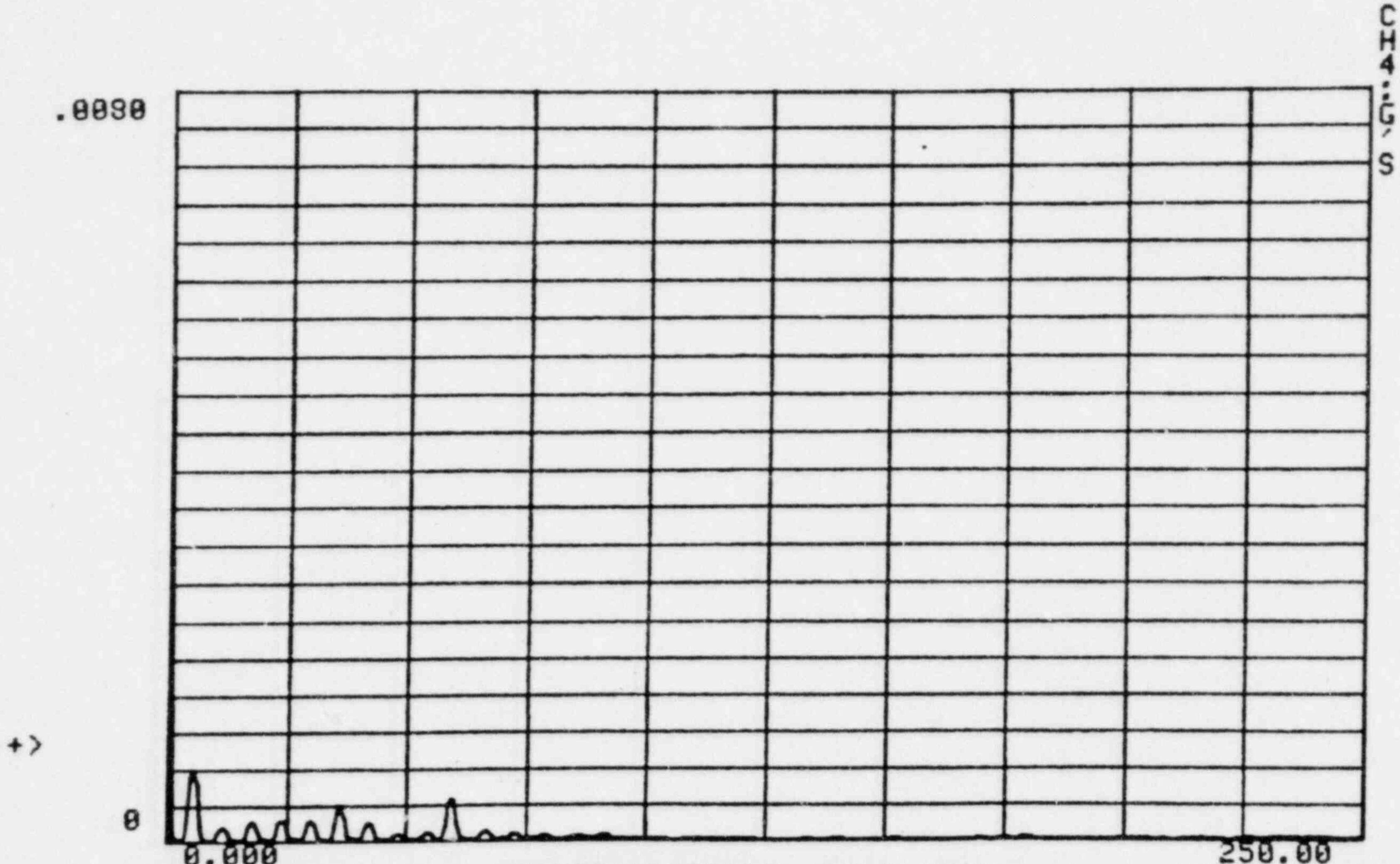

4/1
MNS 1 75% PWR. 40BY 3/19/82
#AVGS=150
FHC#=20
CH4:G/S
.0900
0
+>
0.000
250.00
SPECTRUM: CH.4 (HZ)

FIGURE 45

4/1 MHS 1 75% PWR. 40BY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.4 (HZ)

FIGURE 46

4/1 MNS #1 30% PWR. 40BY 3/19/82 #AVGS=150 FNC#=24

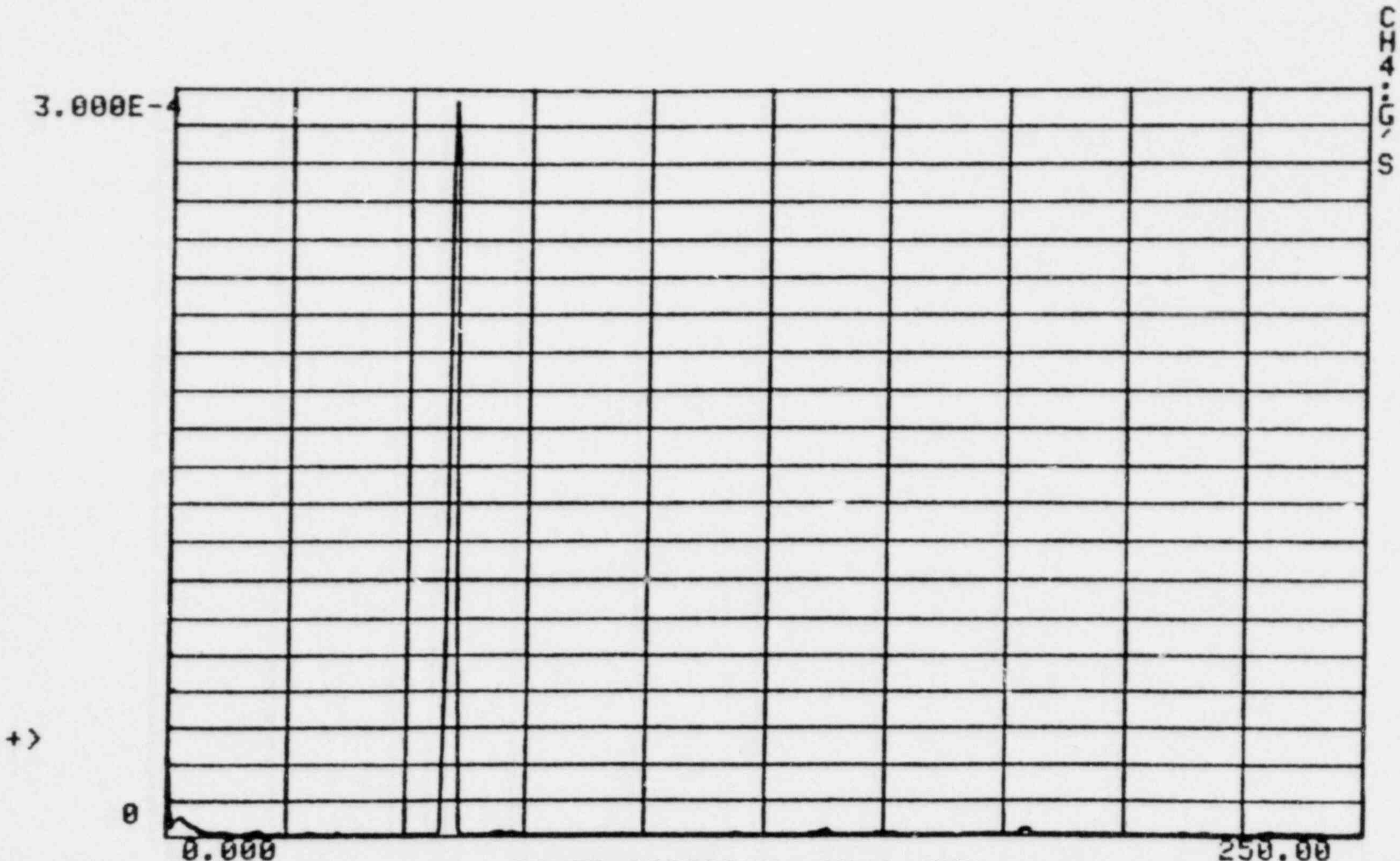


FIGURE 47

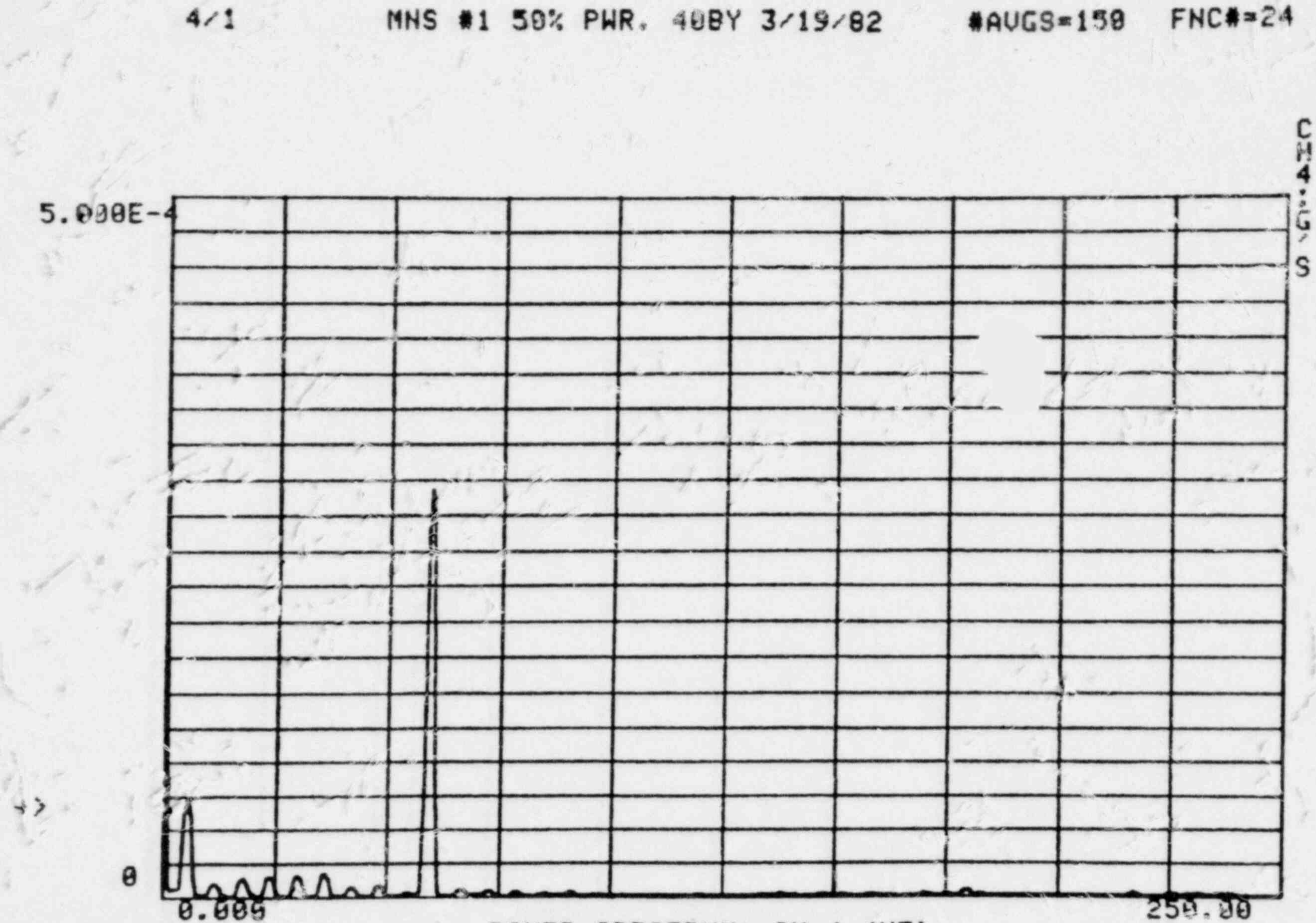
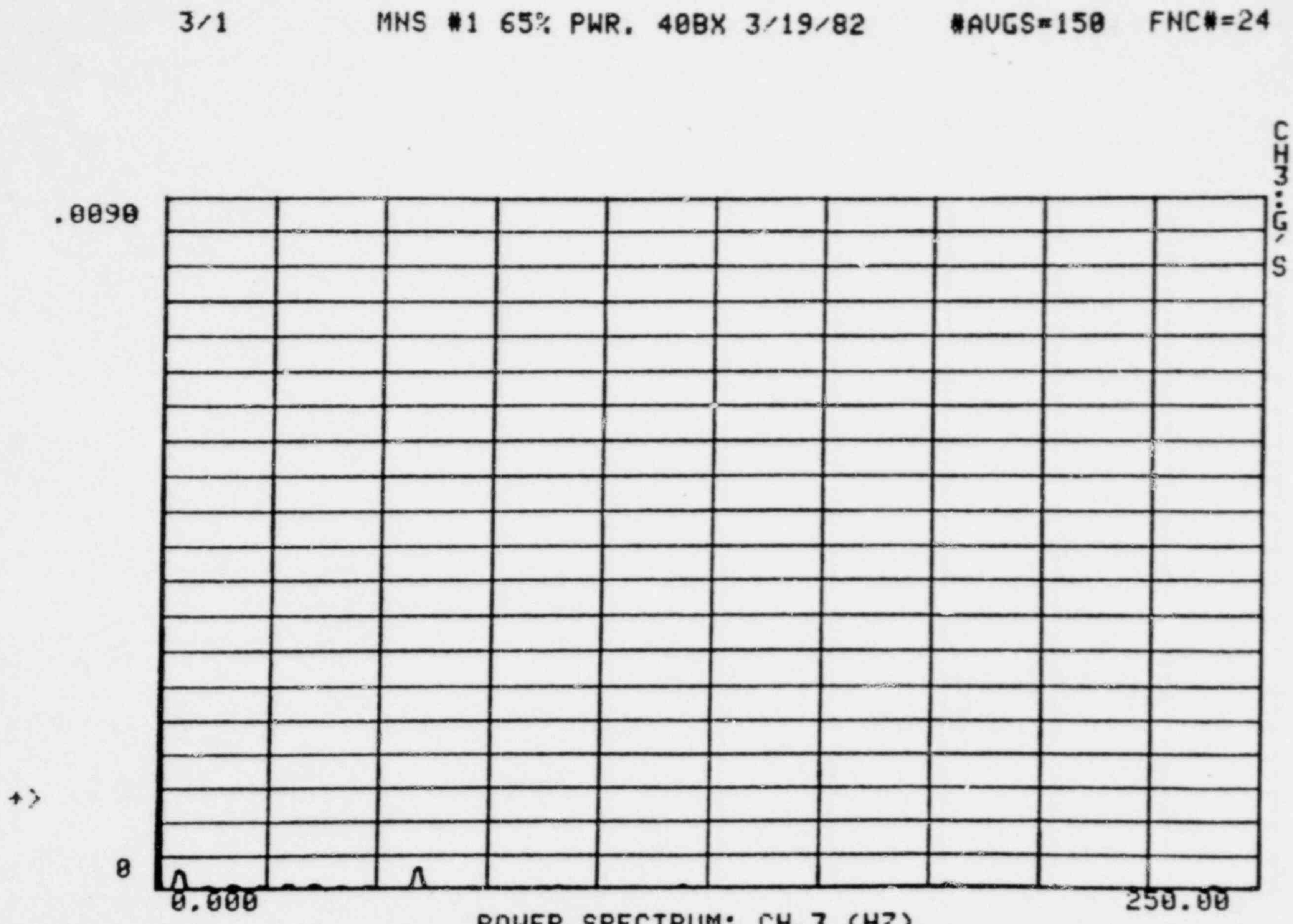

4/1
MNS #1 50% PWR, 40BY 3/19/82
#AVGS=150
FNC#=24
CH4:G/S
5.000E-4
0
0.000
250.00
POWER SPECTRUM: CH.4 (HZ)

FIGURE 48



3/1
MNS #1 65% PWR. 40BX 3/19/82
#AVGS=150
FNC#=24
CH3:G/S
.0090
0
0.000
250.00
POWER SPECTRUM: CH.3 (HZ)

FIGURE 49

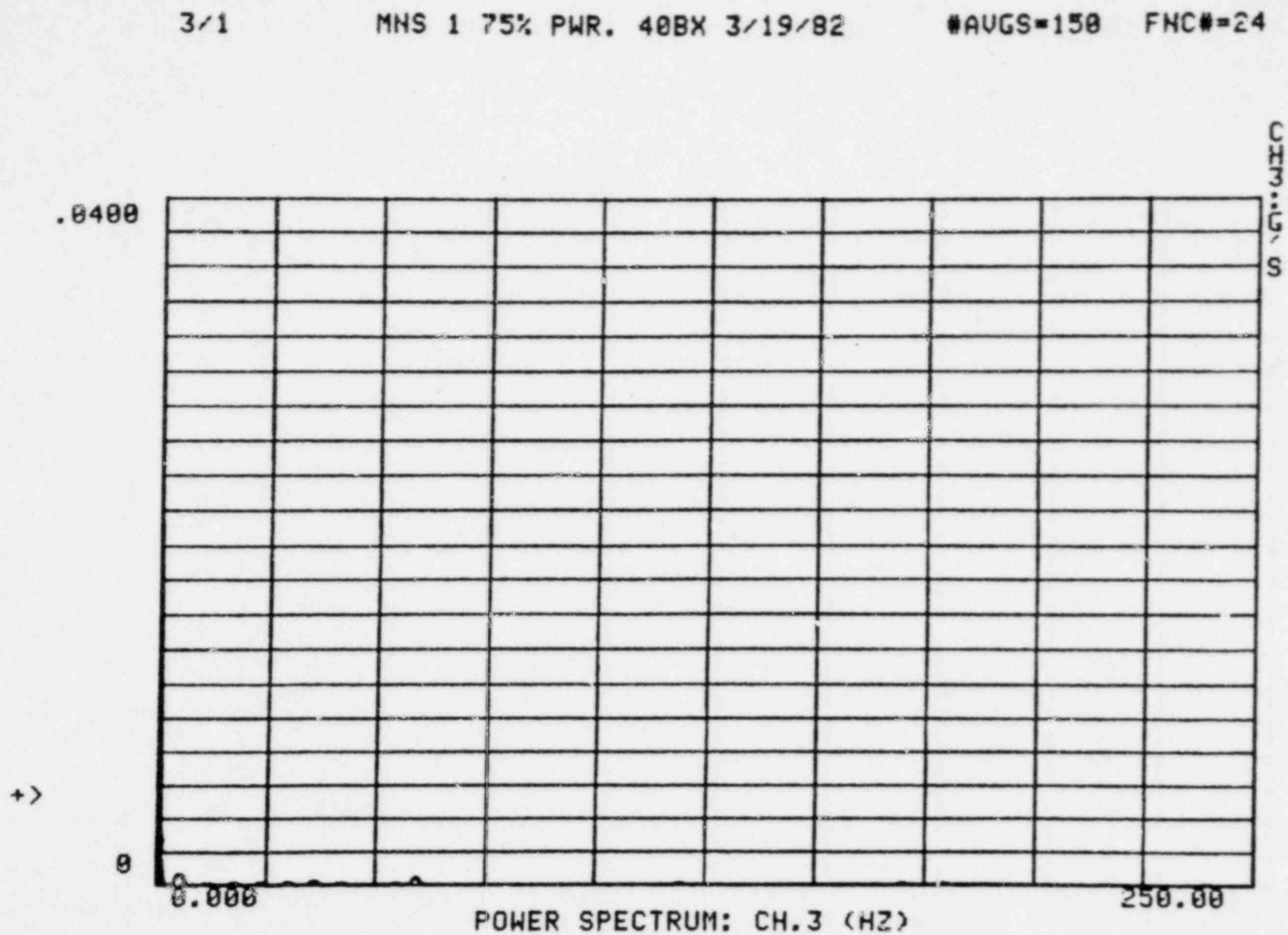

3/1
MHS 1 75% PWR. 40BX 3/19/82
#AVGS=150
FNC#=24
CH3:G's
.0400
+>
0
0.000
250.00
POWER SPECTRUM: CH.3 (HZ)

FIGURE 50

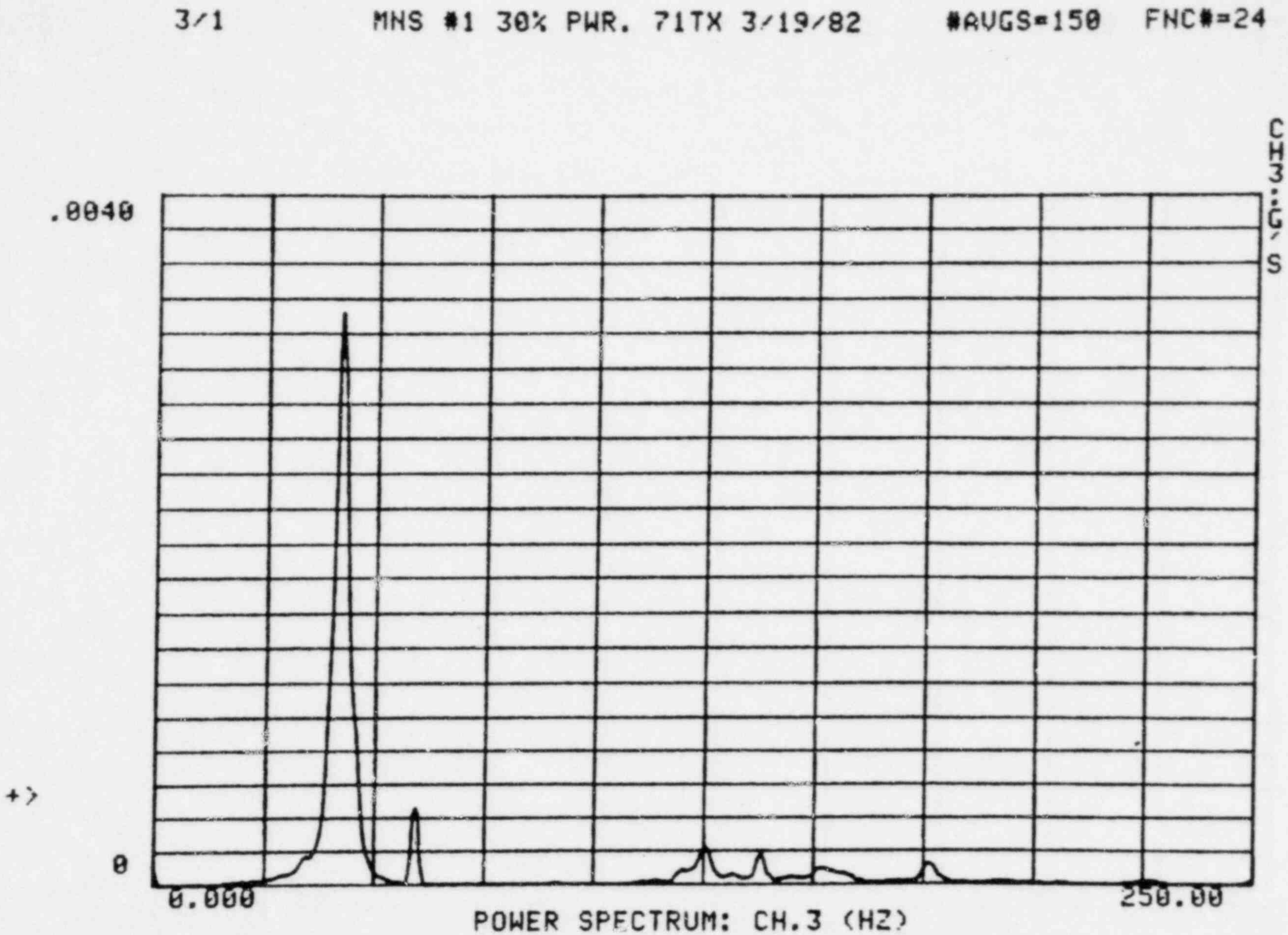

3/1
MHS #1 30% PWR. 71TX 3/19/82
#AVGS=150
FNC#=24
CH3:G/S
.0040
0
+>
0.000
250.00
POWER SPECTRUM: CH.3 (HZ)

FIGURE 51

3/1 MNS #1 50% PWR. 71TX 3/19/82 #AVGS=150 FNC#=24

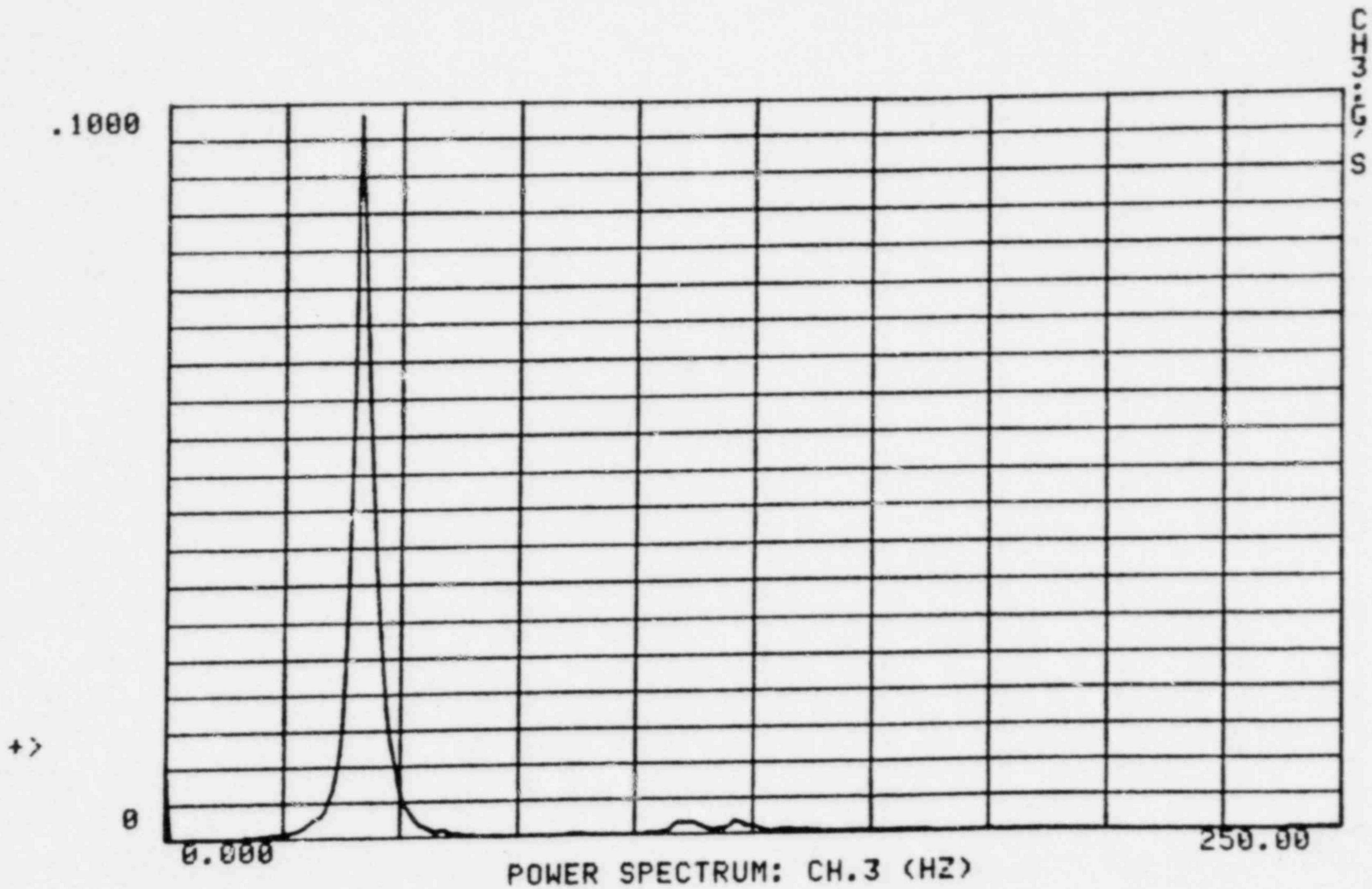
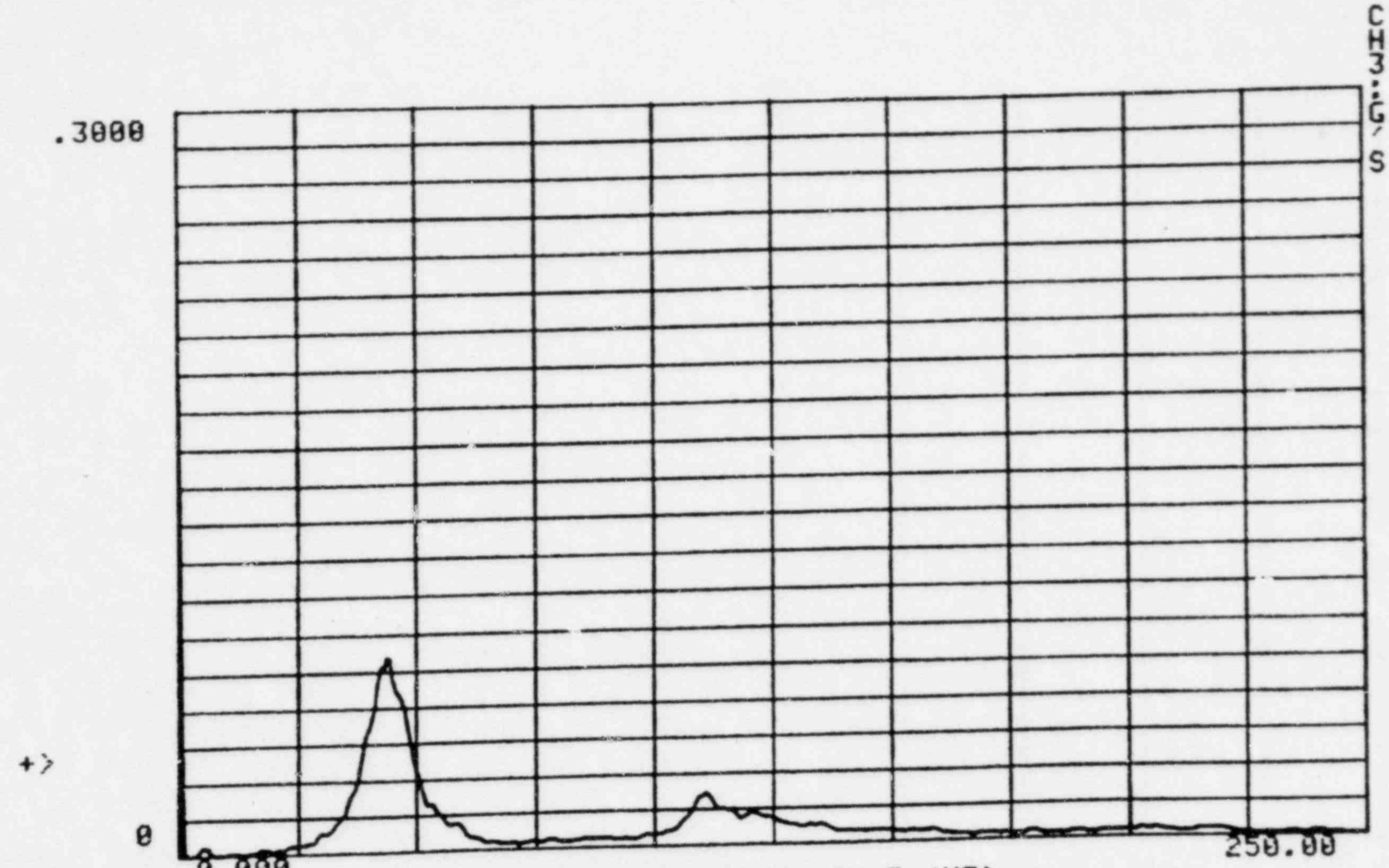


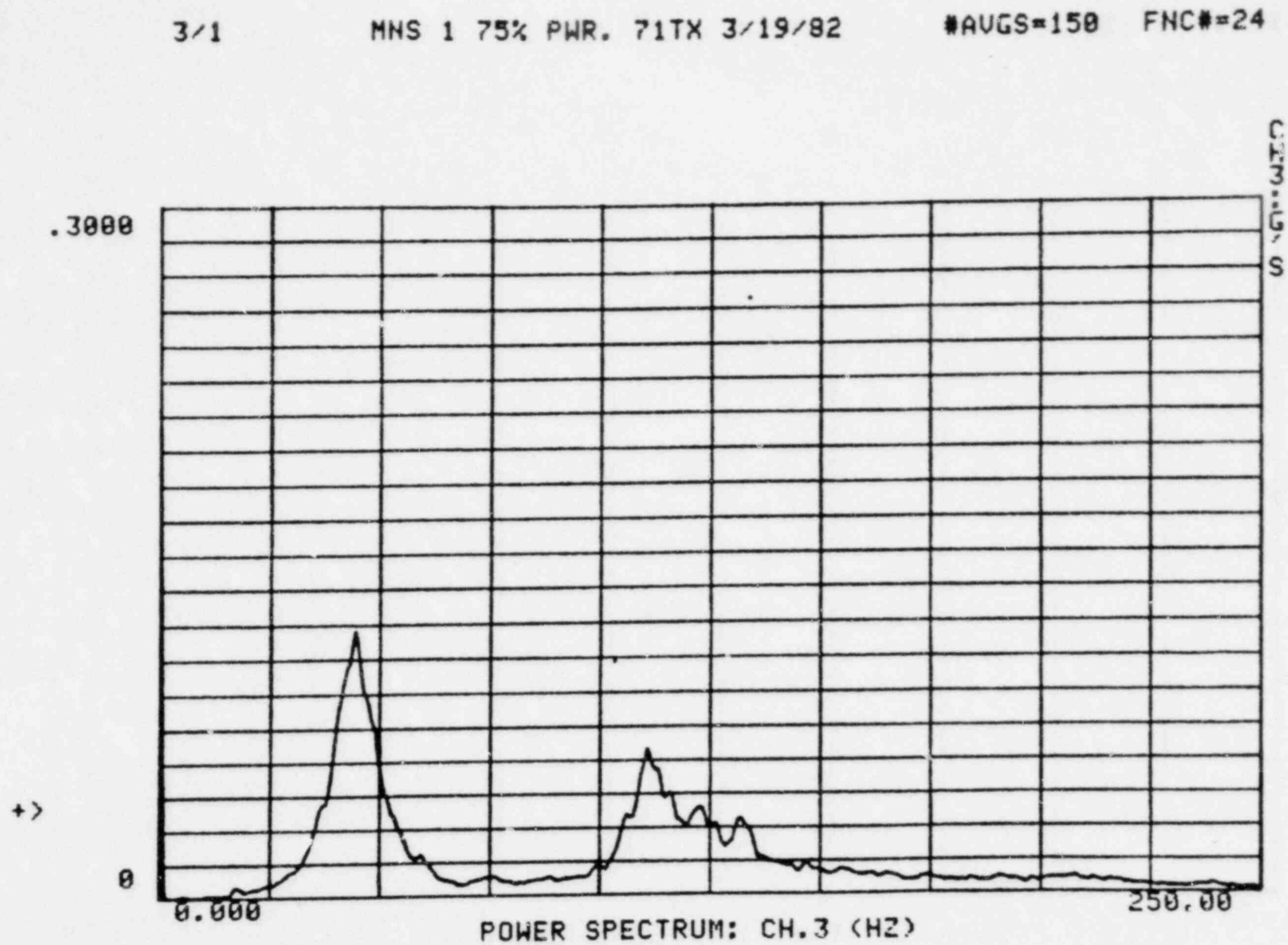
FIGURE 52

3/1   MNS #1 65% PWR. 71TX 3/19/82   #AVGS=150   FNC#=24



POWER SPECTRUM: CH.3 (HZ)

FIGURE 53



3/1
MNS 1 75% PWR. 71TX 3/19/82
#AVGS=150
FNC#=24
.3000
0
+>
0.000
250.00
POWER SPECTRUM: CH.3 (HZ)
S

FIGURE 54

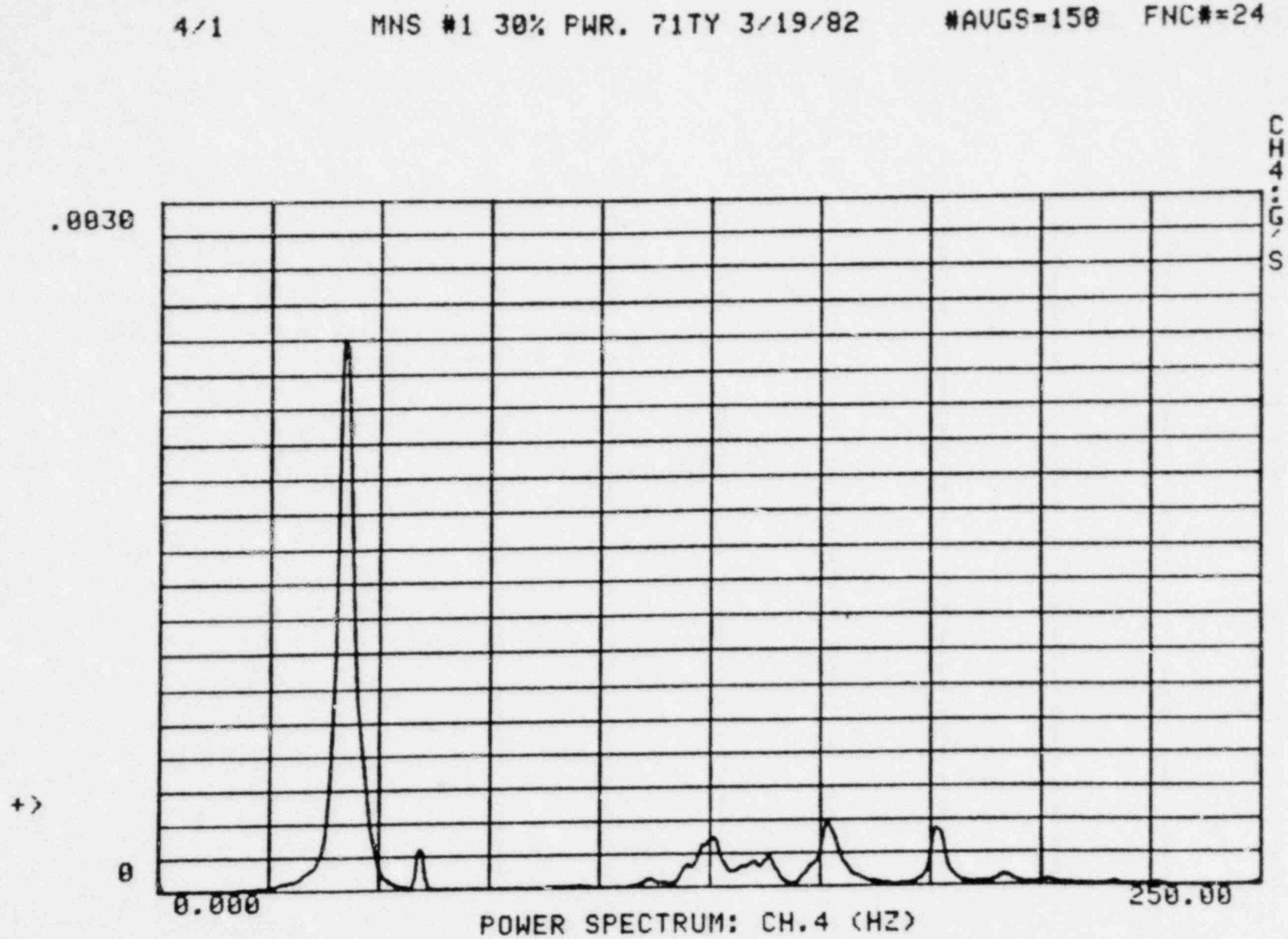
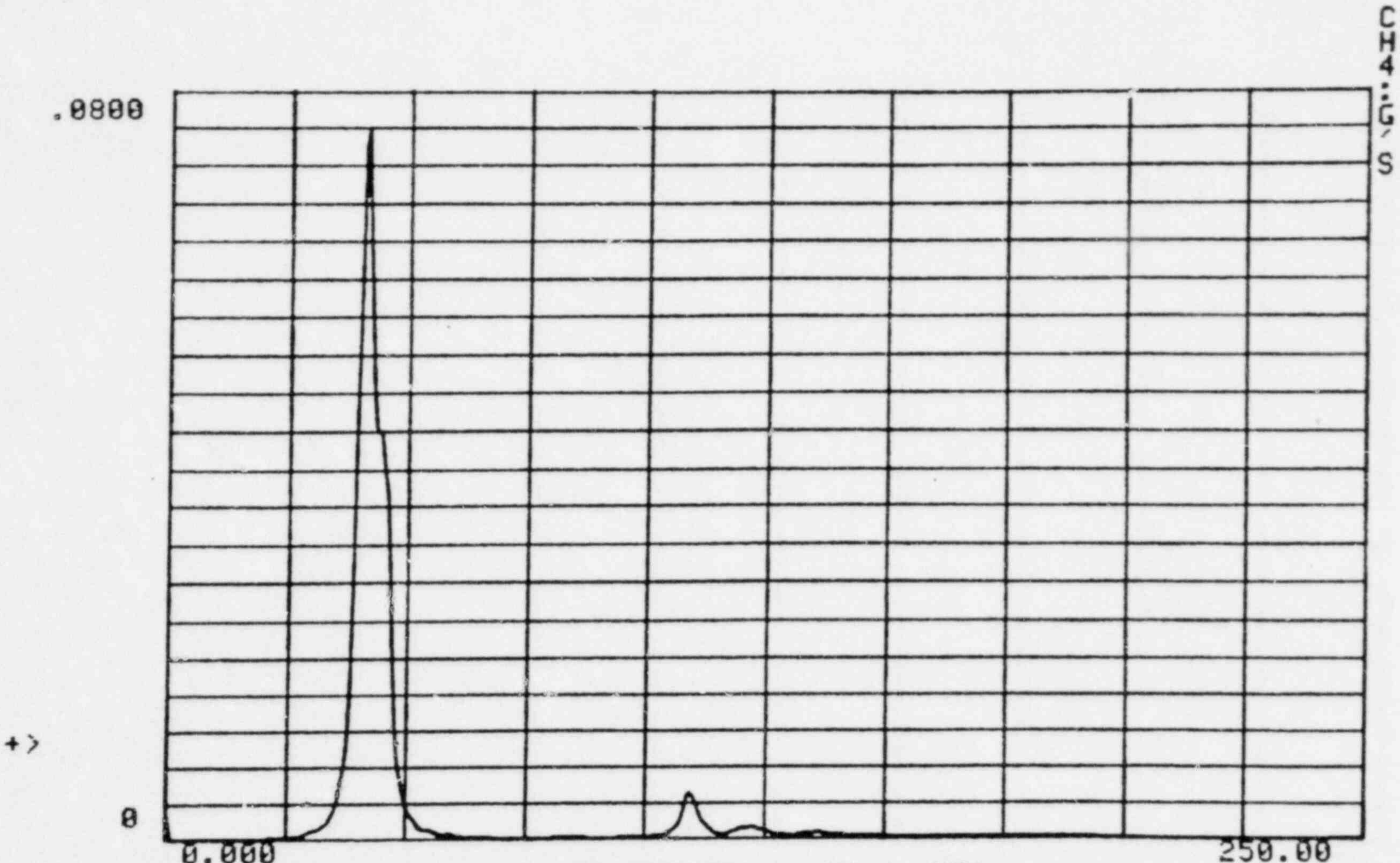

4/1
MNS #1 30% PWR. 71TY 3/19/82
#AVGS=150
FNC#=24
CH4:G/S
.0030
0
+>
0.000
250.00
POWER SPECTRUM: CH.4 (HZ)

FIGURE 55

4/1 MNS #1 50% PWR. 71TY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.4 (HZ)

FIGURE 56

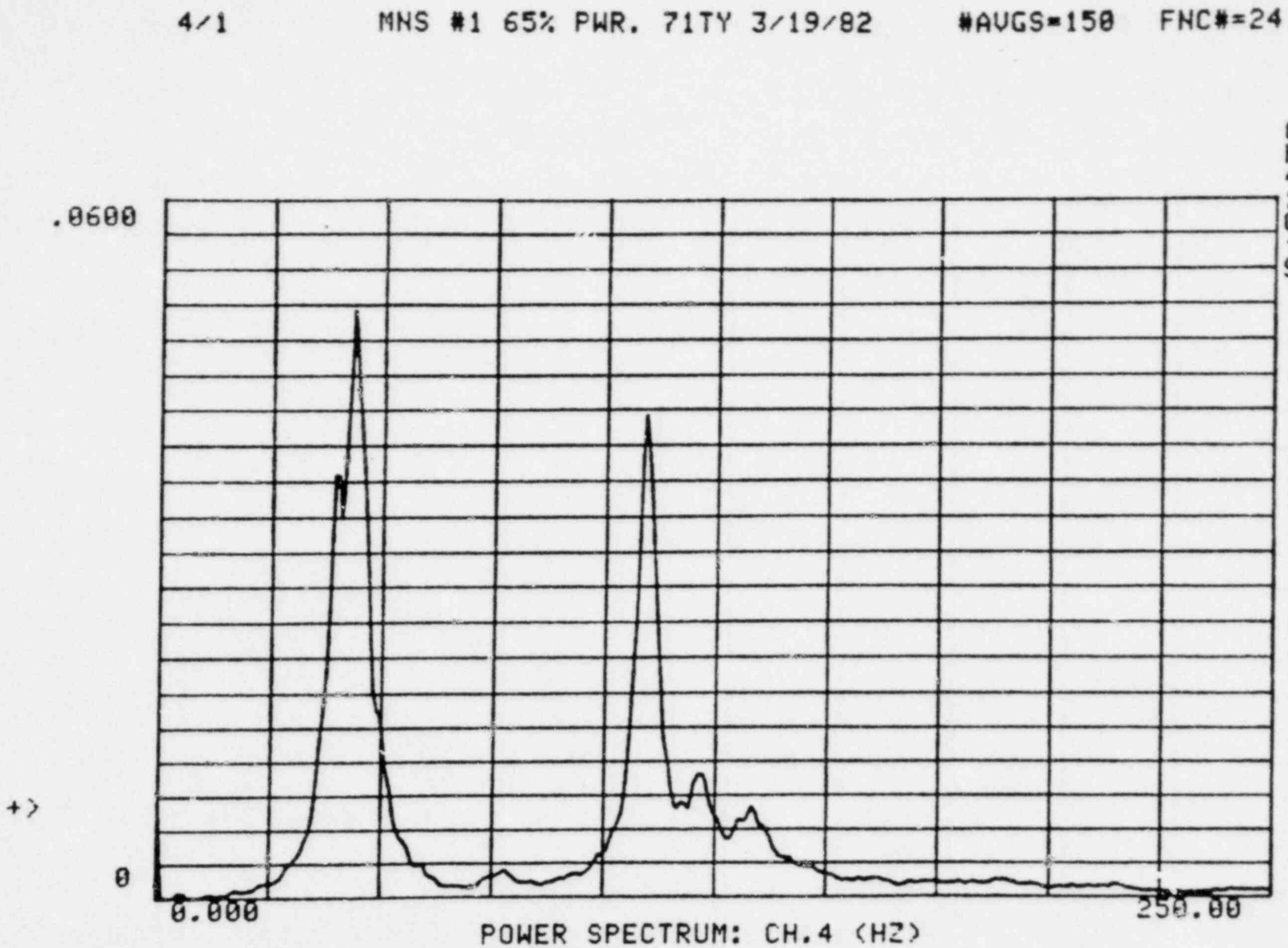
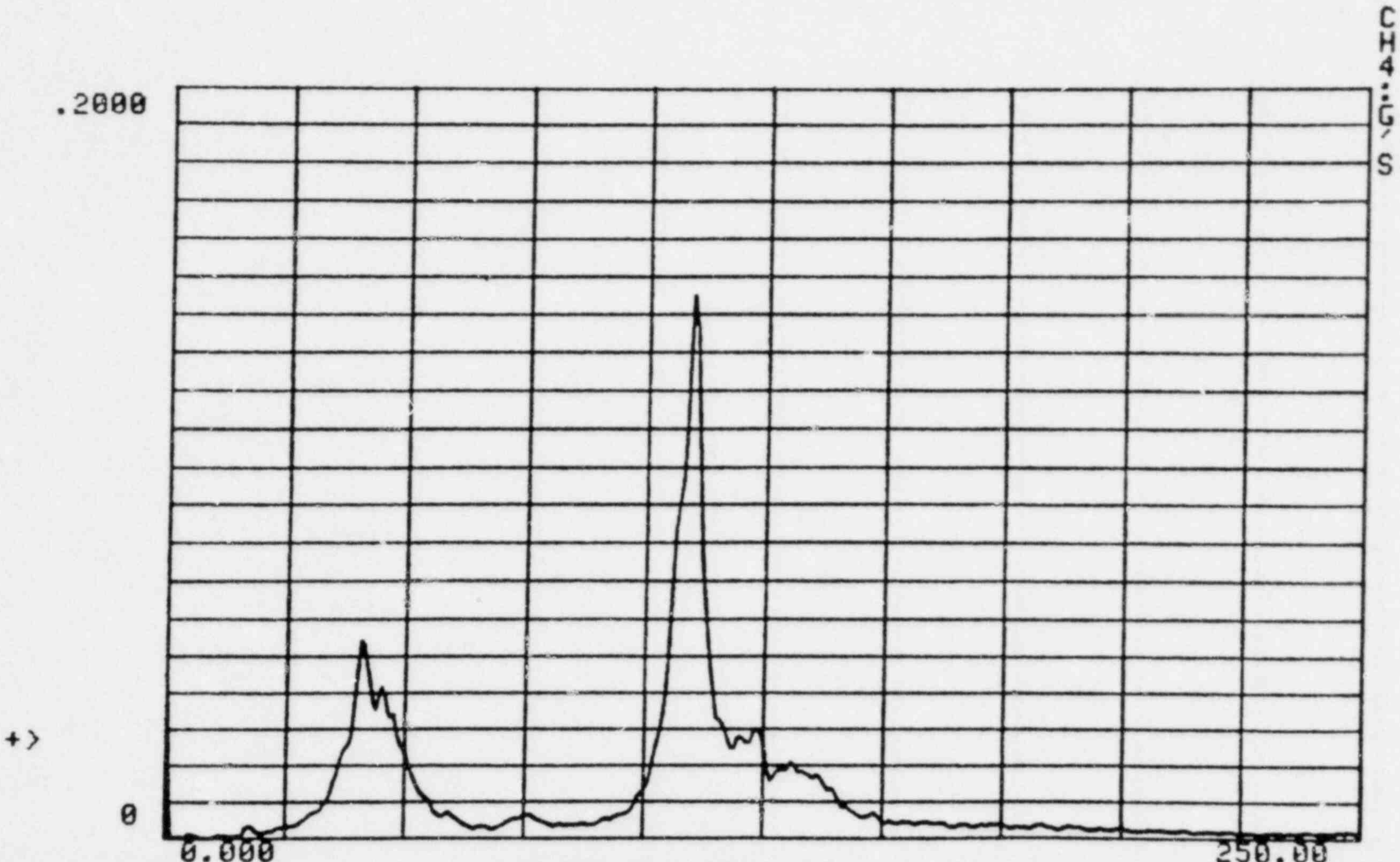

4/1
MNS #1 65% PWR. 71TY 3/19/82
#AVGS=150
FNC#=24
CH4:G/S
.0600
+>
0
0.000
250.00
POWER SPECTRUM: CH.4 (HZ)

FIGURE 57

4/1 MNS 1 75% PWR. 71TY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.4 (HZ)

FIGURE 58

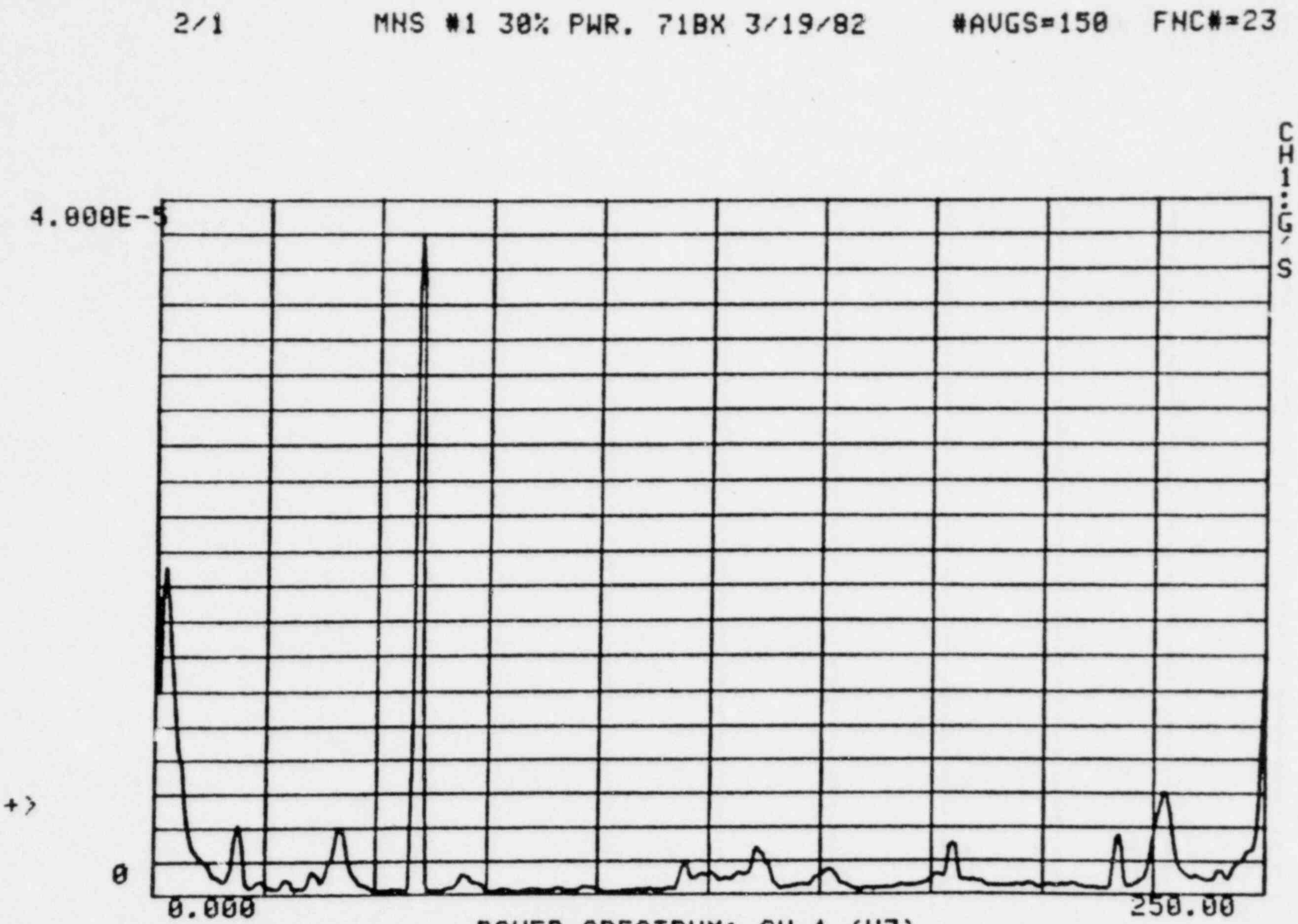

2/1
MHS #1 30% PWR. 71BX 3/19/82
#AVGS=150
FNC#=23
CH1:G/S
4.000E-5
+>
0
0.000
250.00
POWER SPECTRUM: CH.1 (HZ)

FIGURE 59

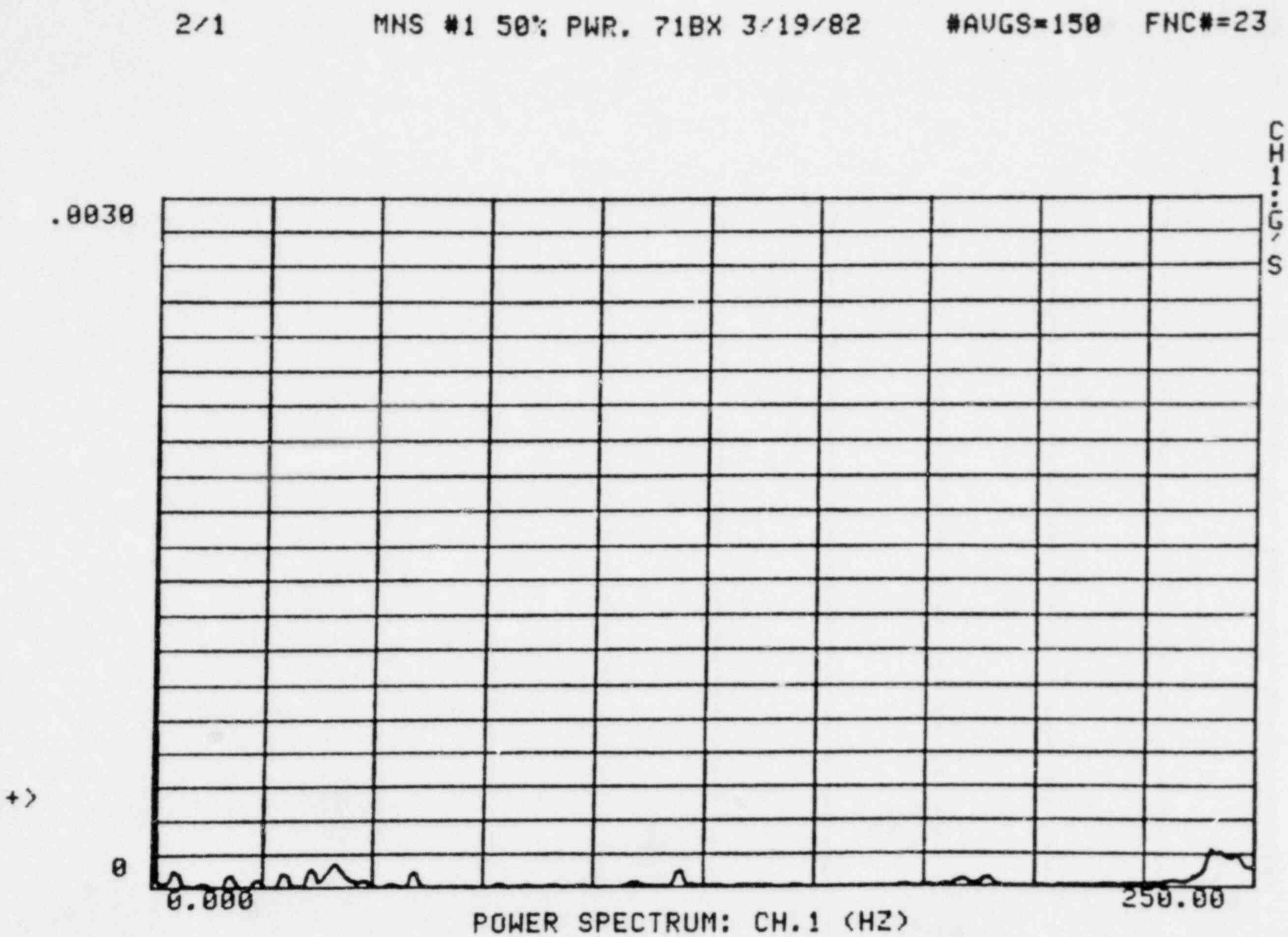

2/1
MNS #1 50% PWR. 71BX 3/19/82
#AVGS=150
FNC#=23
CH1:G/S
.0030
+>
0
0.000
250.00
POWER SPECTRUM: CH.1 (HZ)

FIGURE 60

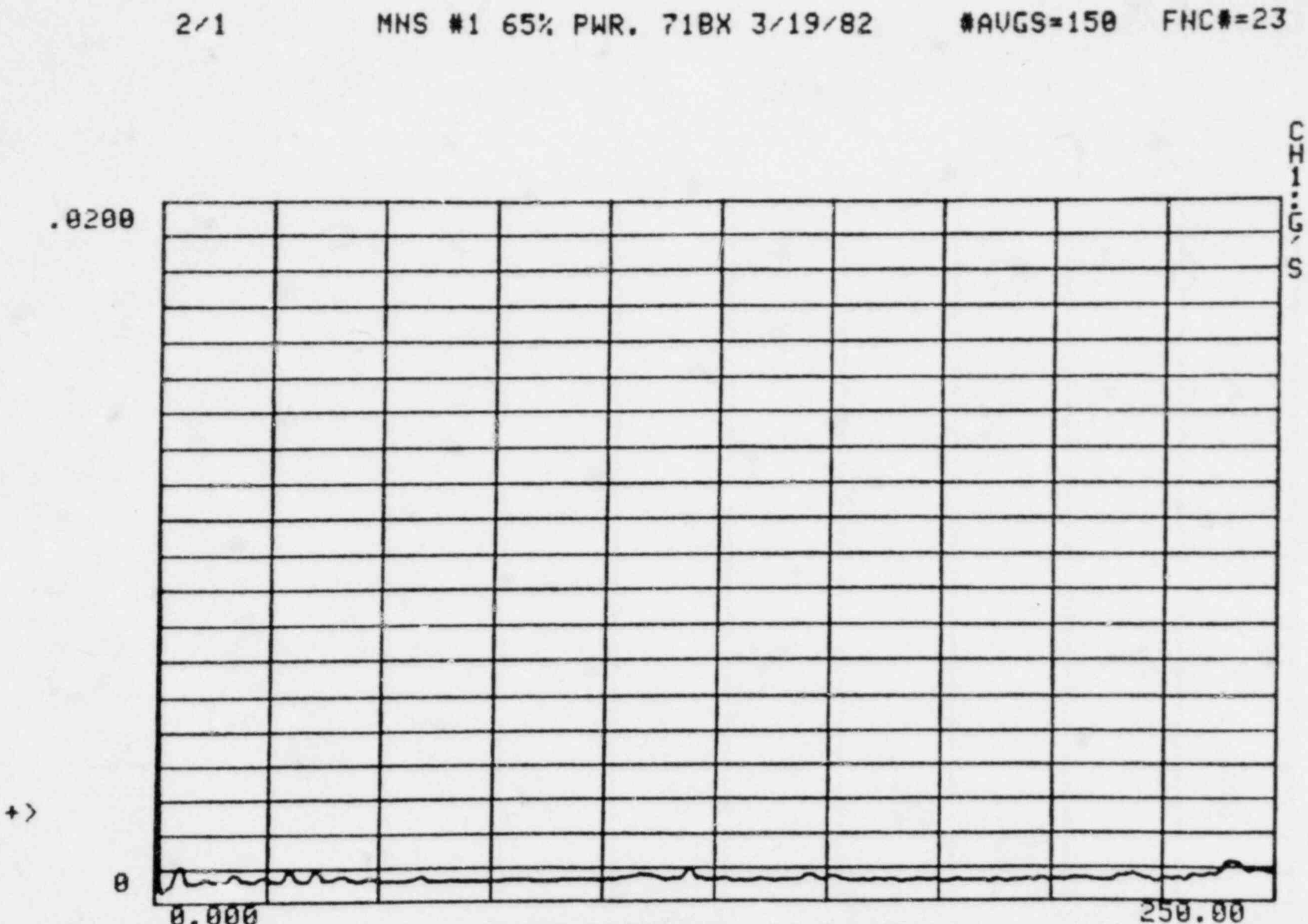

2/1 MNS #1 65% PWR. 71BX 3/19/82 #AVGS=150 FNC#=23
.0200
0
0.000
250.00
CH1:G/S
POWER SPECTRUM: CH.1 (HZ)

FIGURE 61

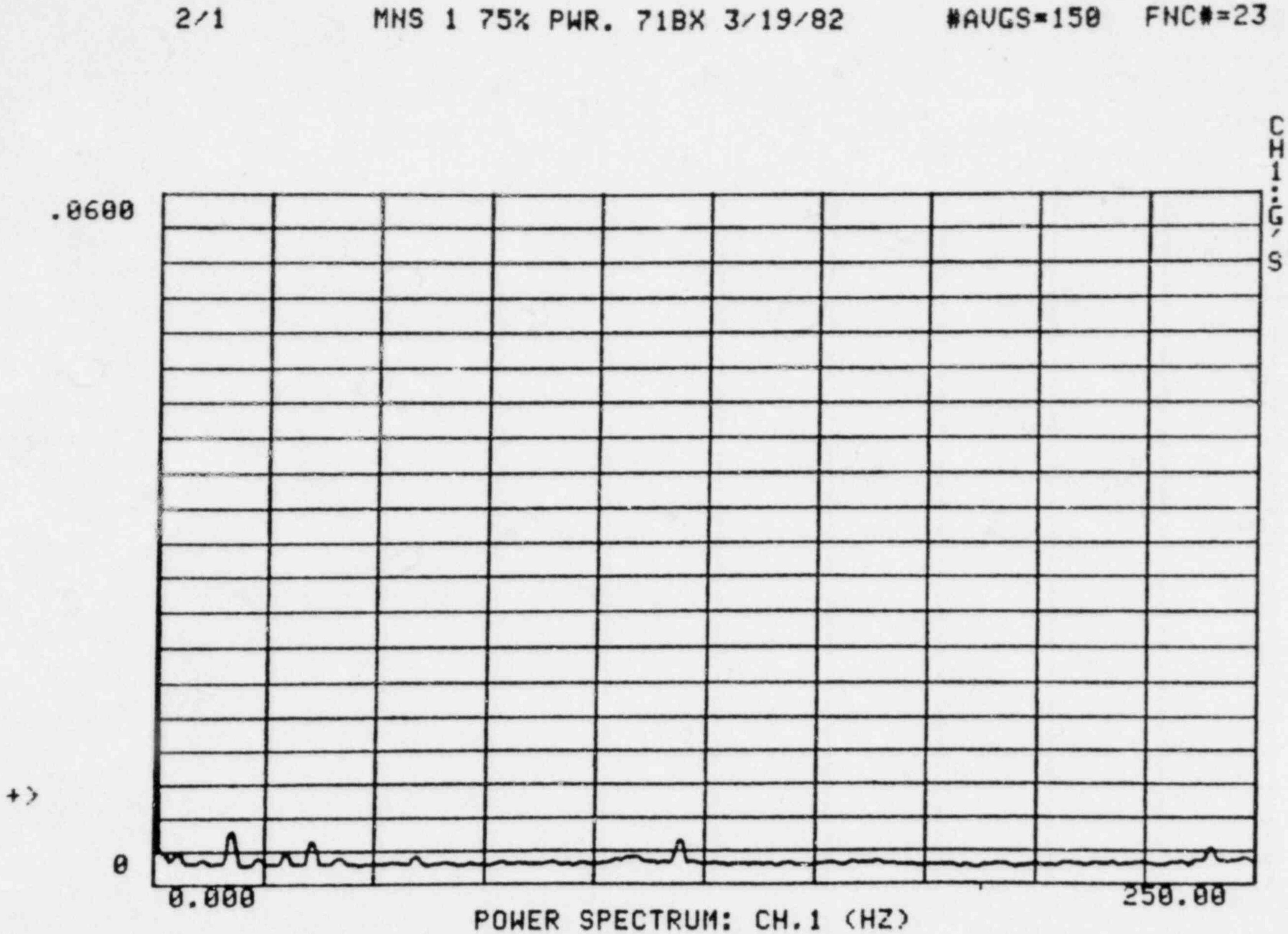
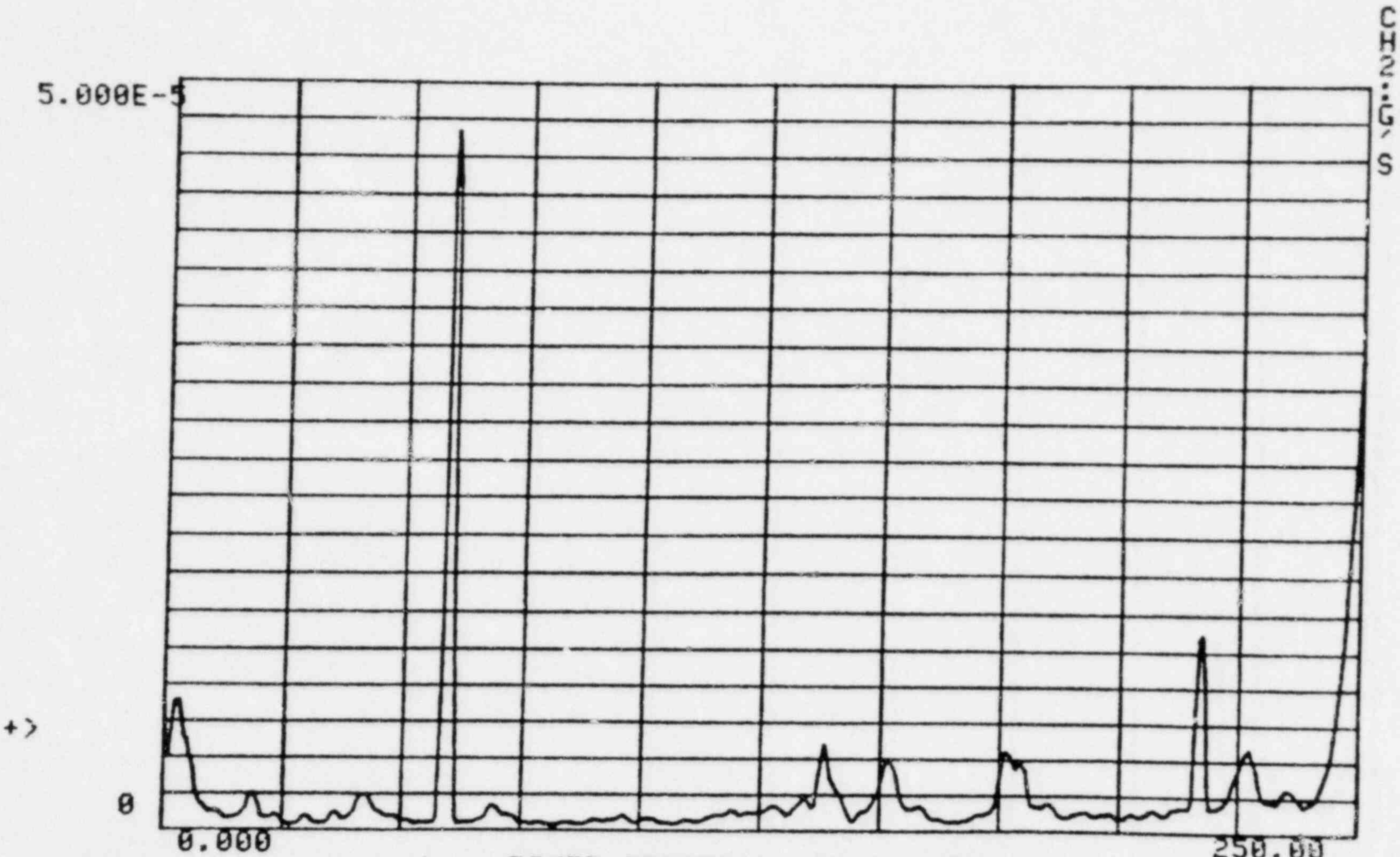

2/1
MNS 1 75% PWR. 71BX 3/19/82
#AVGS=150
FNC#=23
CH1:G'S
.0600
+>
0
0.000
250.00
POWER SPECTRUM: CH.1 (HZ)

FIGURE 62

2/1 MNS #1 30% PWR. 71BY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.2 (HZ)

FIGURE 63

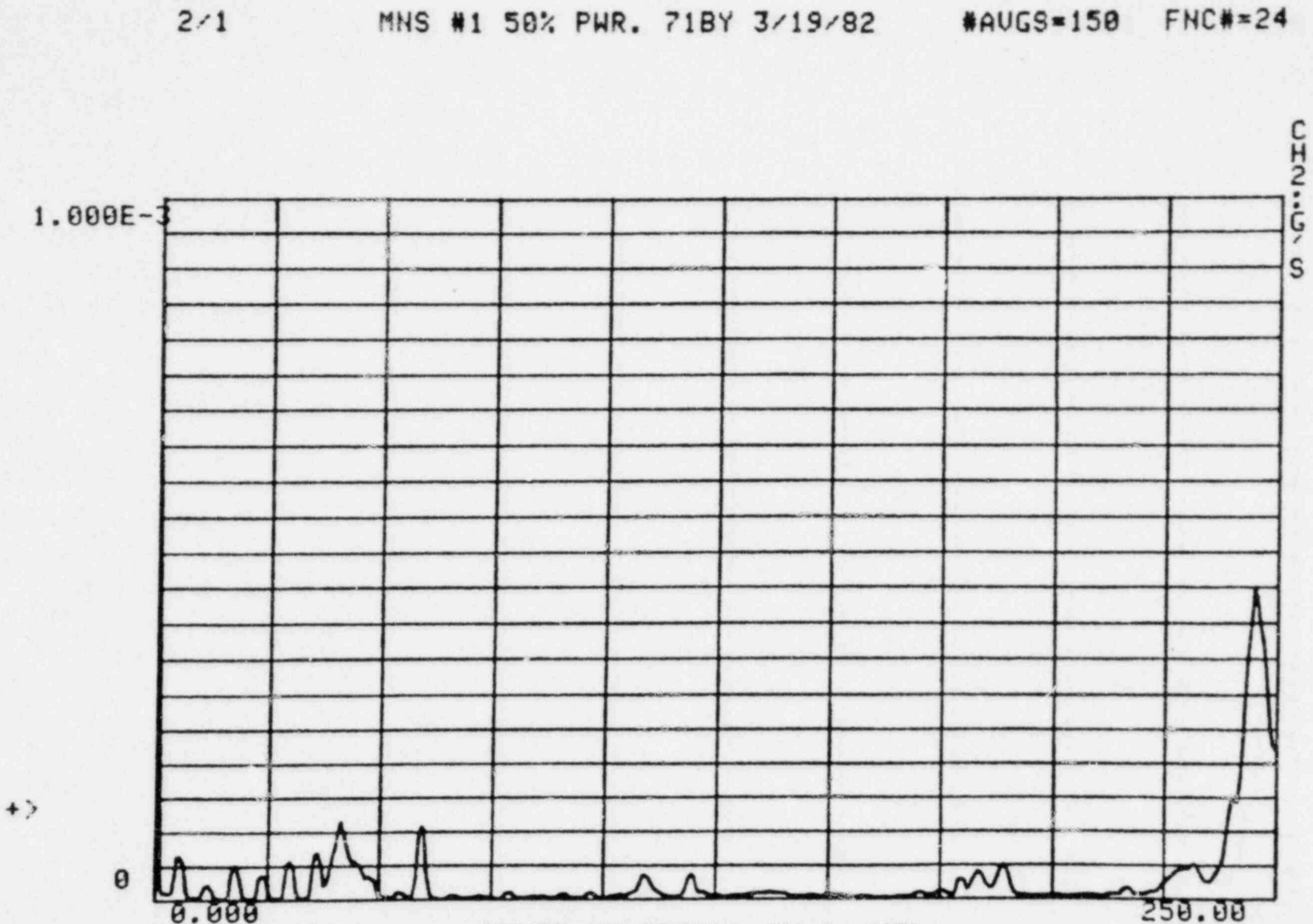

2/1
MNS #1 50% PWR. 71BY 3/19/82
#AVGS=150
FNC#=24
CH2:G/S
1.000E-3
0
0.000
250.00
POWER SPECTRUM: CH.2 (HZ)

FIGURE 64

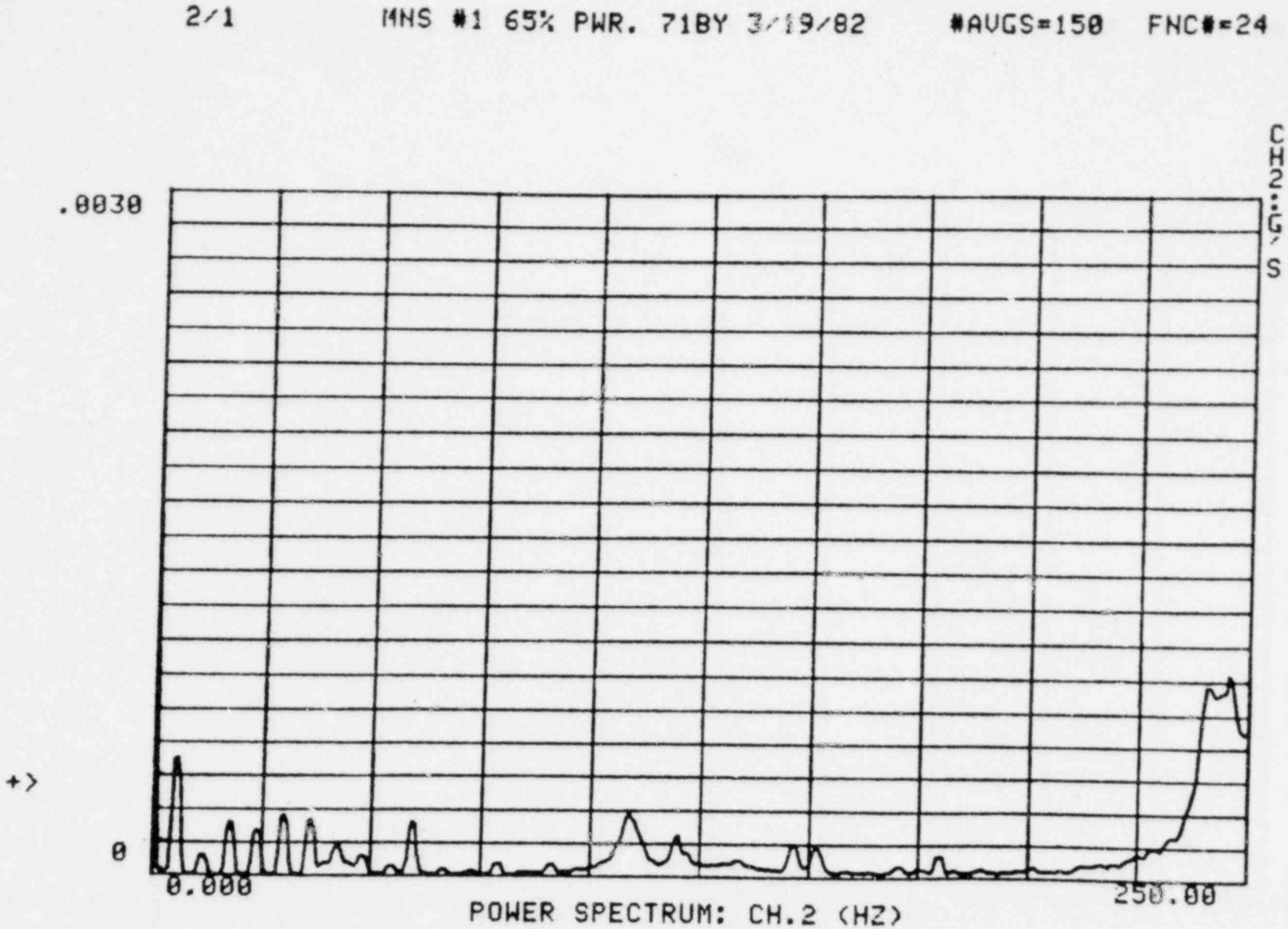
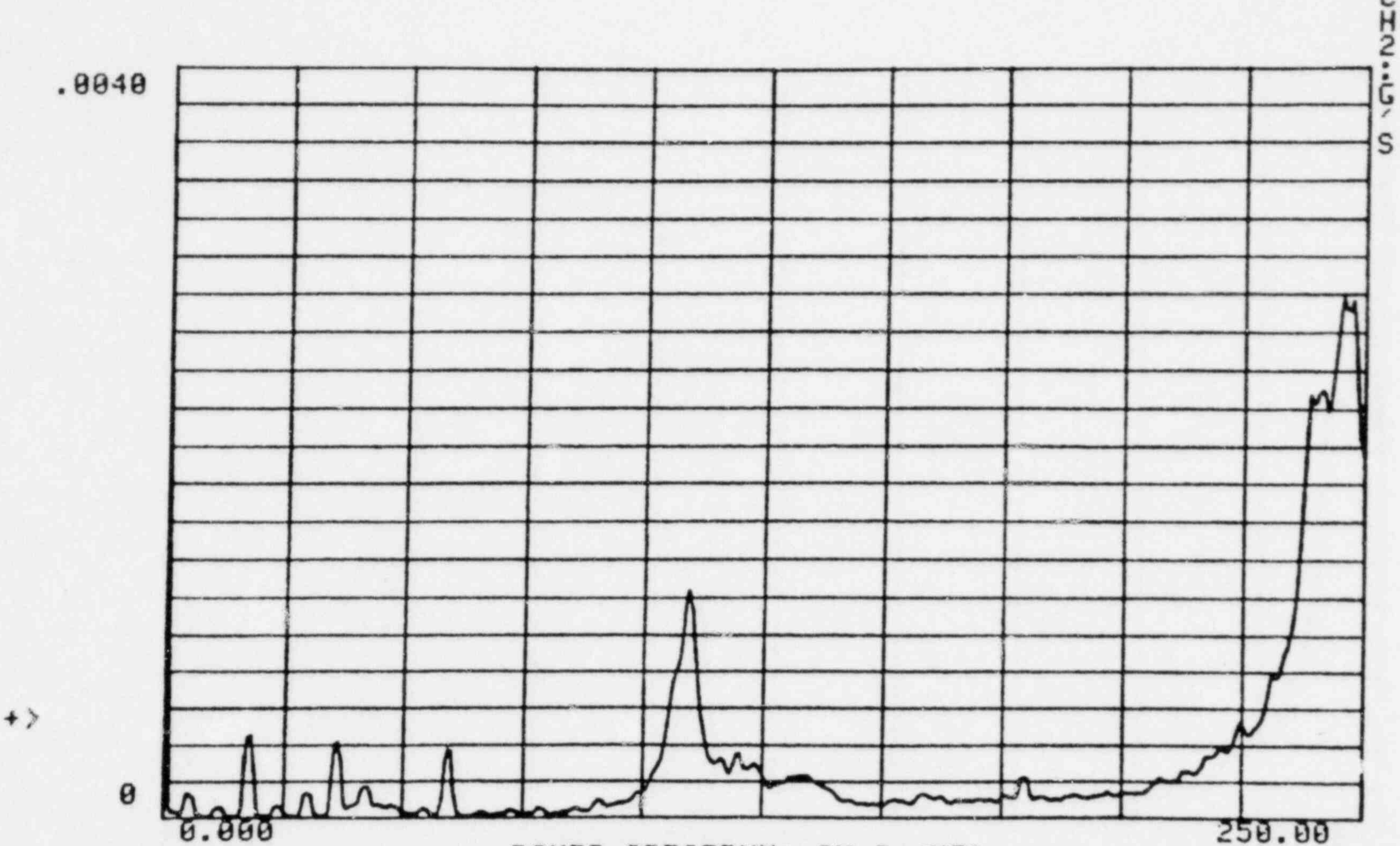

2/1
MNS #1 65% PWR. 71BY 3/19/82
#AVGS=150
FNC#=24
CH2:G/S
.0030
+>
0
0.000
250.00
POWER SPECTRUM: CH.2 (HZ)

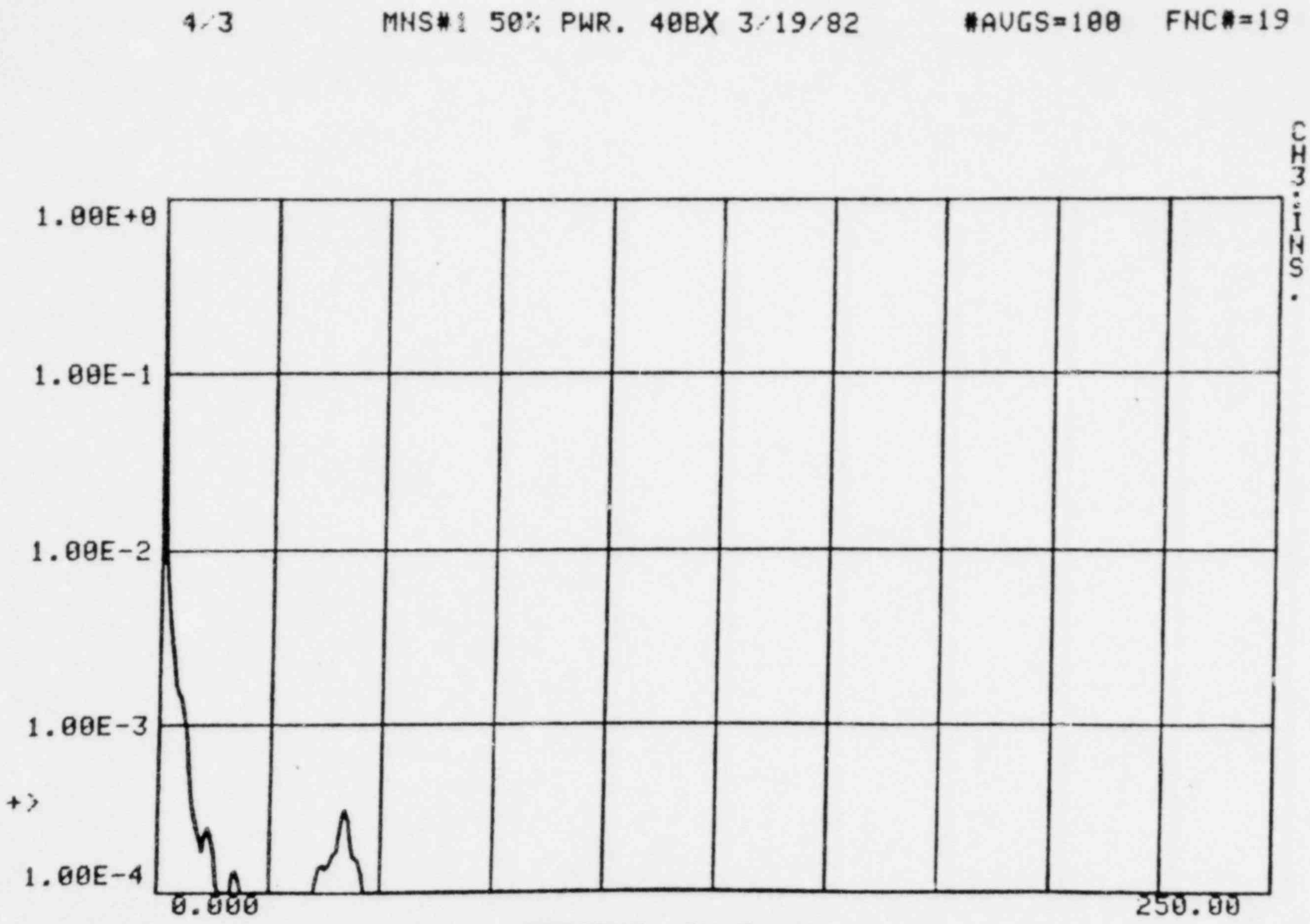
FIGURE 65

2/1 MNS 1 75%PWR. 71 BY 3/19/82 #AVGS=150 FNC#=24



POWER SPECTRUM: CH.2 (HZ)

FIGURE 66



4/3
MNS#1 50% PWR. 40BX 3/19/82
#AVGS=100
FNC#=19
CH3:INS.
1.00E+0
1.00E-1
1.00E-2
1.00E-3
1.00E-4
0.000
250.00
SPECTRUM: CH.3 (HZ)

FIGURE 67

4/3 MNS#1 50% PWR. 40BY 3/19/82 #AVGS=100 FNC#=20

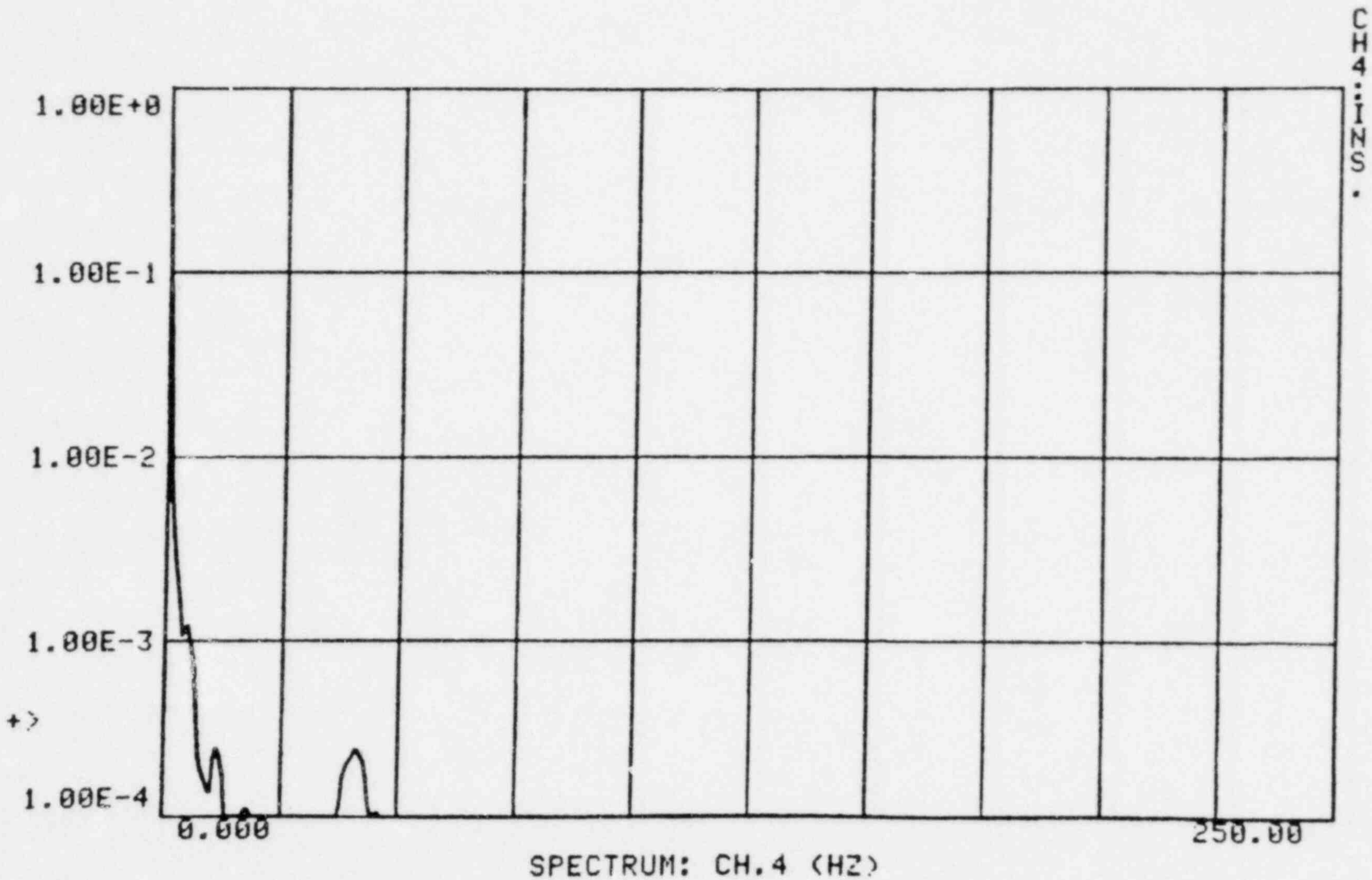


FIGURE 6B

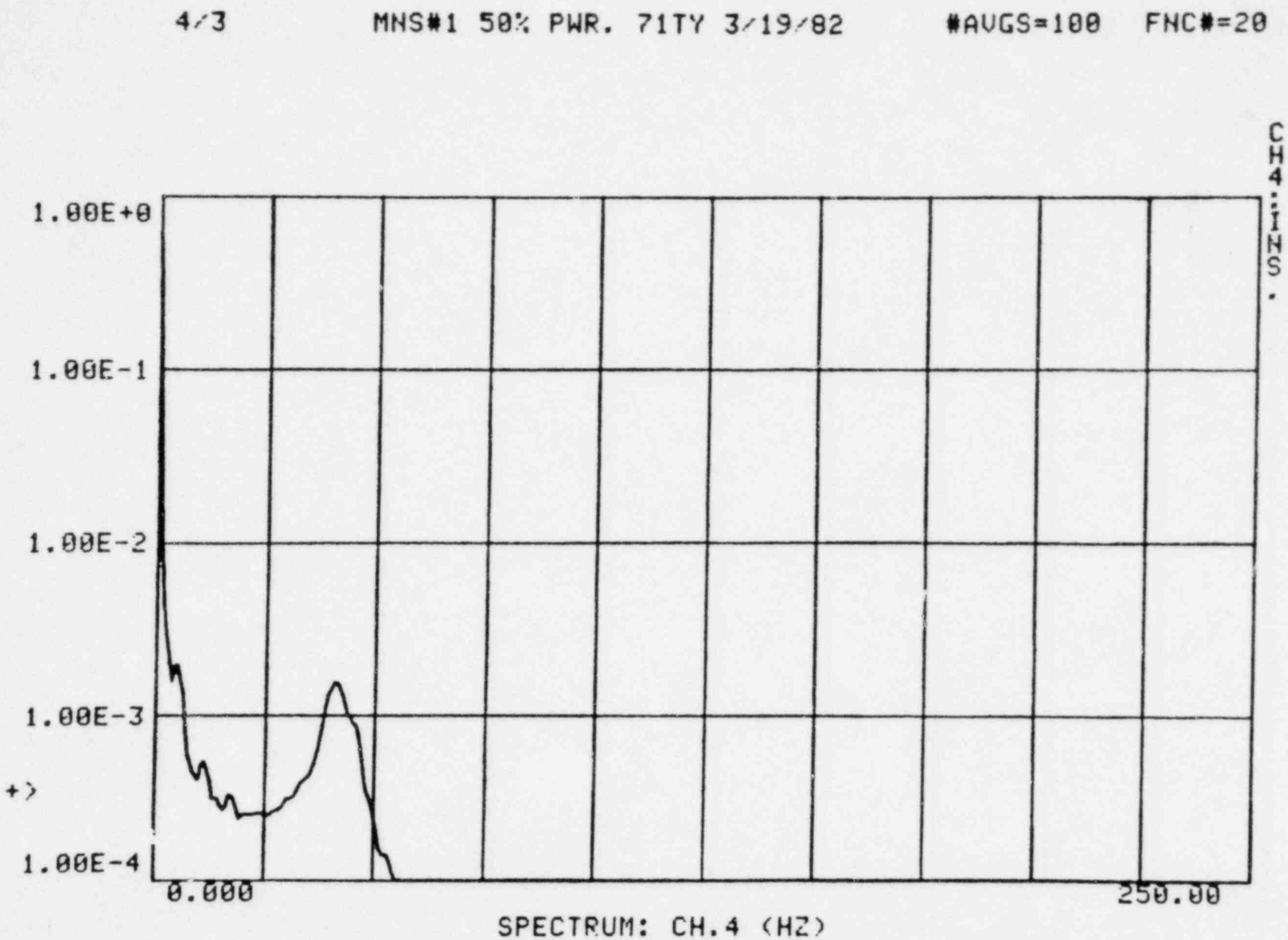

4/3
MNS#1 50% PWR. 71TY 3/19/82
#AVGS=100
FNC#=20
CH4:INS.
1.00E+0
1.00E-1
1.00E-2
1.00E-3
+>
1.00E-4
0.000
250.00
SPECTRUM: CH.4 (HZ)

FIGURE 69

4/3 MNS#1 75% PWR. 71TY 3/19/82 #AVGS=115 FNC#=20

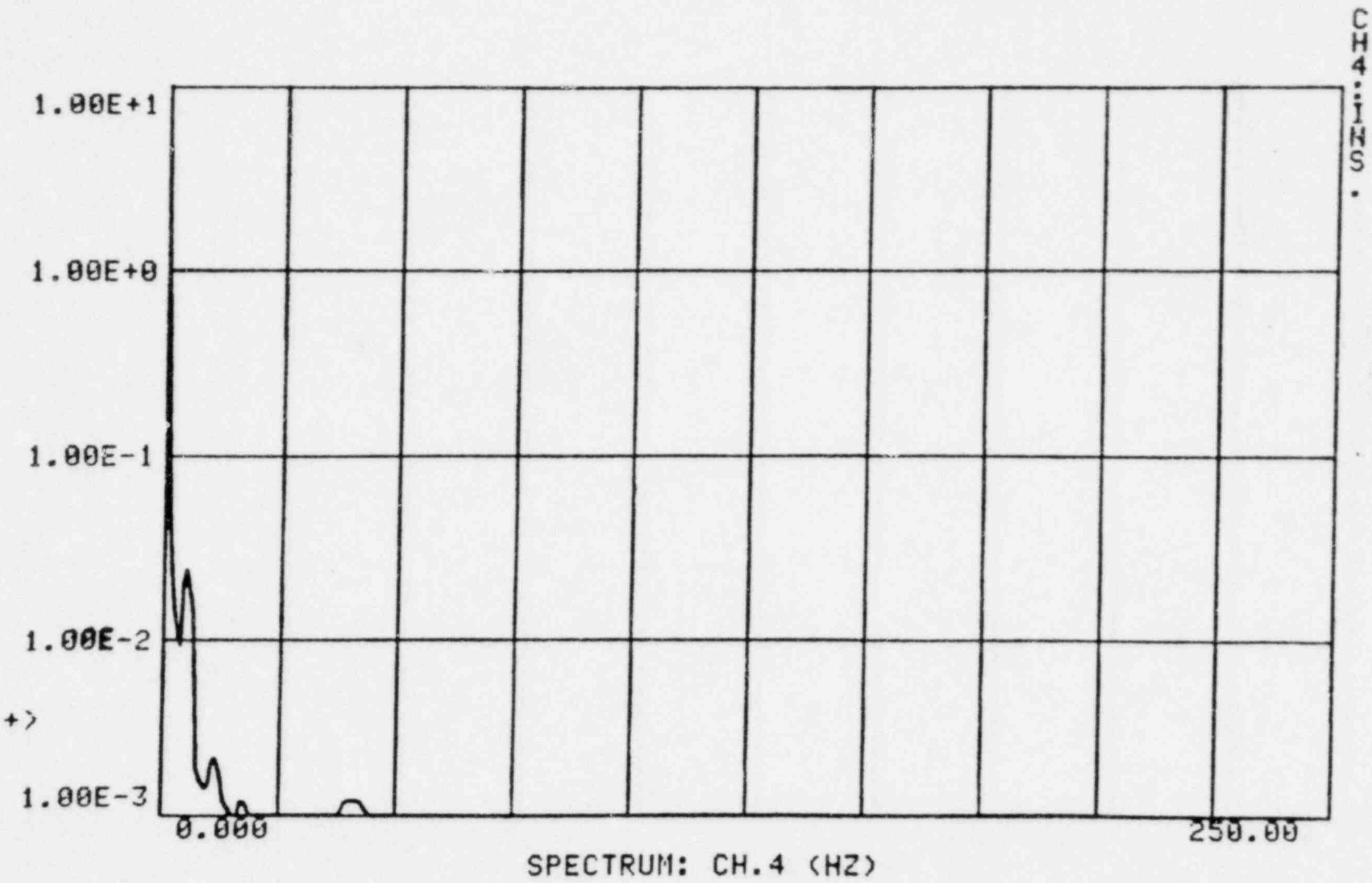
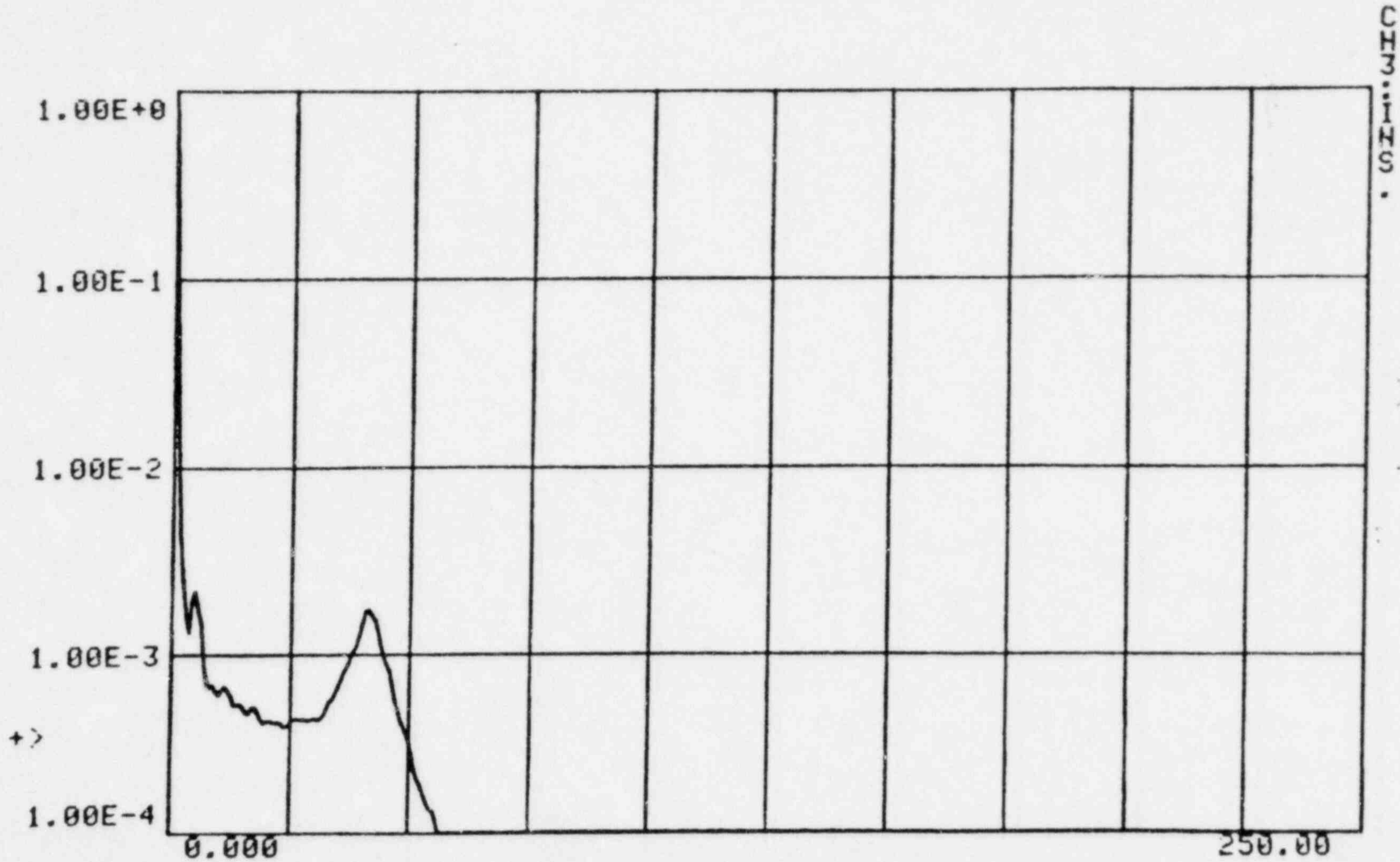


FIGURE 70

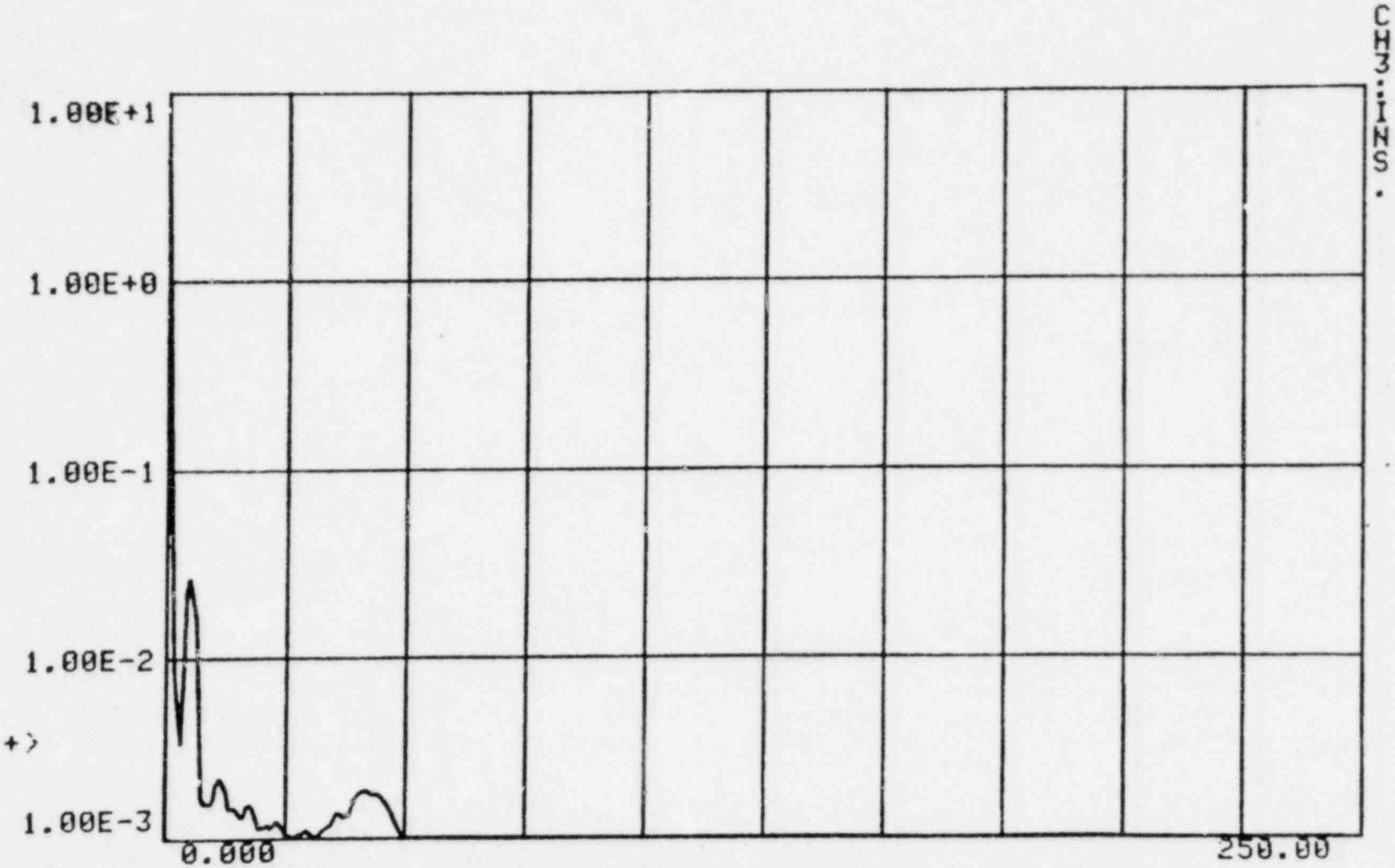
4/3 MHS#1 50% PWR. 71TX 3/19/82 #AVGS=100 FNC#=19



SPECTRUM: CH.3 (HZ)

FIGURE 71

4/3 MNS#1 75% PWR. 71TX 3/19/82 #AVGS=115 FNC#=19



SPECTRUM: CH.3 (HZ)

FIGURE 72

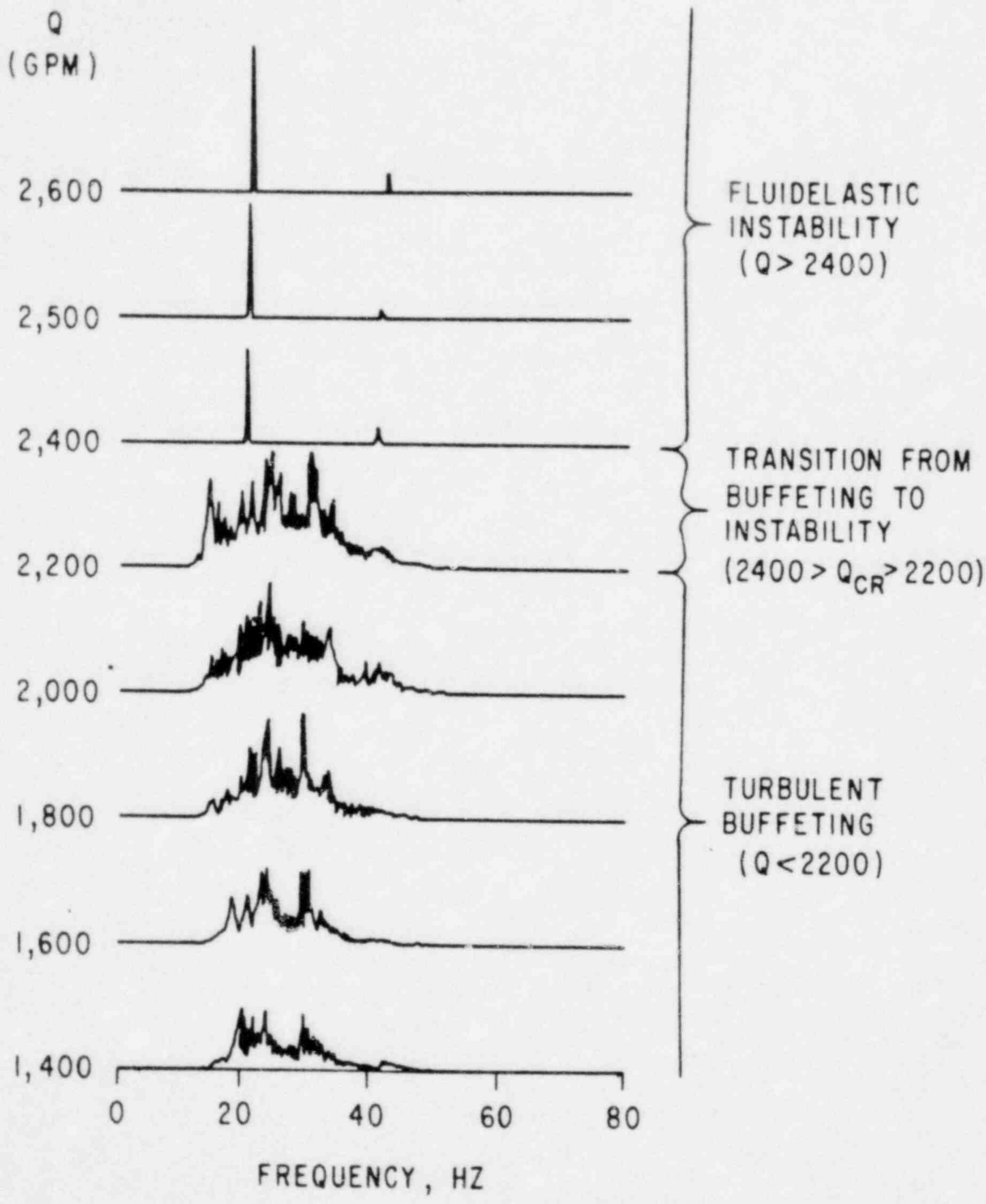


Fig. 5. Tube response PSDs for various shellside flowrates (ordinate not to scale)

FIGURE 73

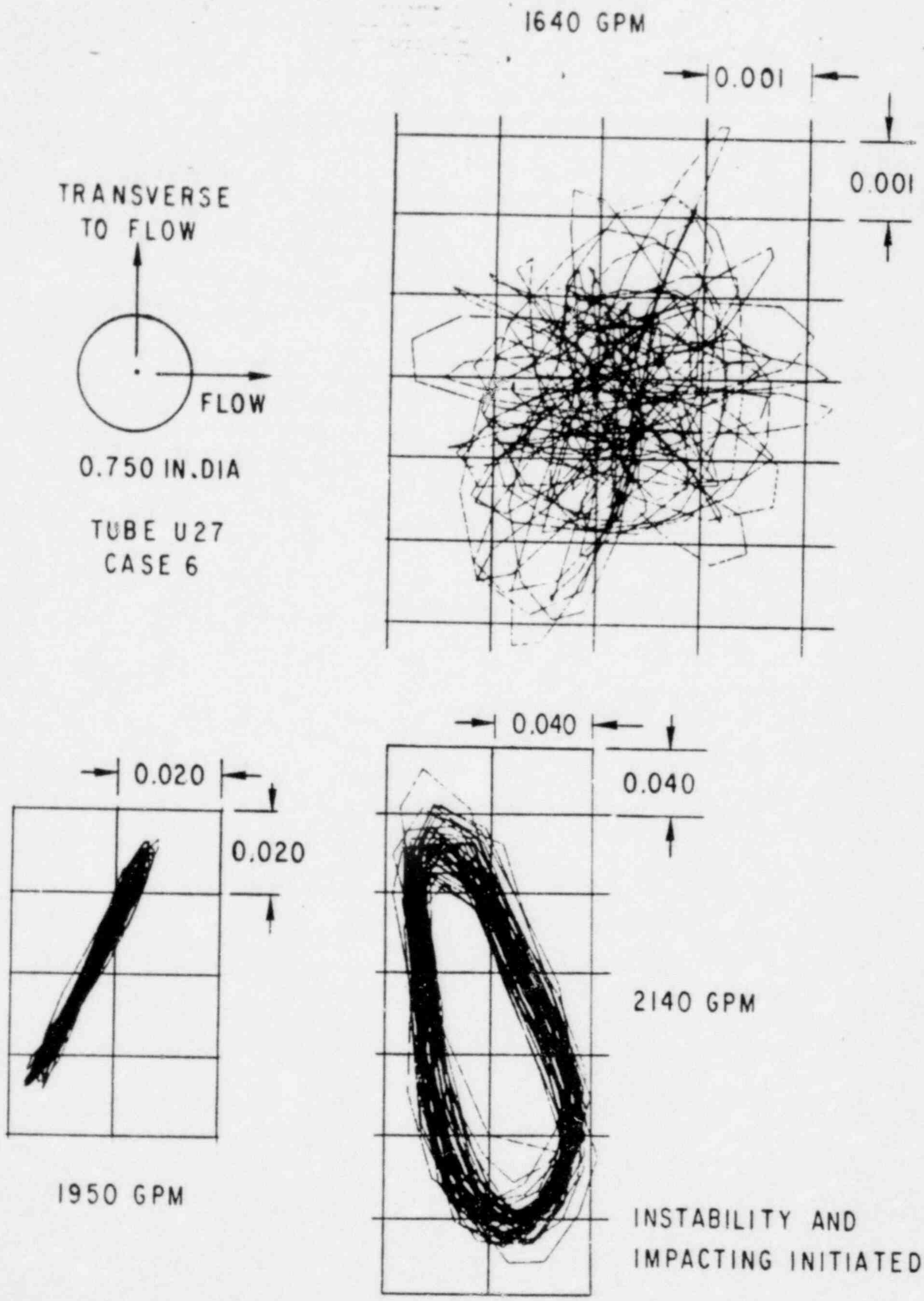


Fig. 13. Tube vibration patterns

FIGURE 74