INVESTIGATIONS INTO THE ALSEP FLIGHT 1 "A" TRANSMITTER ANOMALY

ATM-892

19 JUNE 1970

Prepared by: J. T. Reeves

Approved by: W. Tosh, Supervisor
ALSEP Systems Engineering

INTRODUCTION

The ALSEP Flight 1 downlink monitors experienced loss of lock occasionally while receiving signals from the ALSEP "A" transmitter. Correspondence indicated that changes in AGC level, doubler current level and transmitted frequency may have occurred. Average signal level was reported to have remained constant at -140 dBm. A spectrum analyzer attached to a MSFN receiver 50 MHz input did not reveal any indication of the problem. The rate of dropouts steadily increased to about 1 per minute, until Transmitter "B" was commanded on at 031-03-57-45Z.

This ATM presents the findings from analyses of test data, from available portions of the recorded data and from the communications written during the period of the anomalous performance.

SUMMARY

Short term data recorded around the periods of the anomaly revealed very little information other than to show that some step changes were occurring in the AGC and doubler current housekeeping parameters near the times of the anomalies, but apparently insufficient at those times, to cause the Receiver to loose lock or the "Decom" to loose sync.

A better insight into the possible problem was obtained only after plotting the available transmitter AGC voltage and doubler current values versus temperature over the entire 3 lunar day operating period. Test-history reference points were also plotted.

Several conclusions and inferences may be drawn:

1. The data available from both test and transmission from the Moon provides a very limited source of information for the purposes of "troubleshooting." This will be discussed further in the body of the text.

2. Transmitter "A" is exhibiting step changes in operating mode (as indicated by the step changes in doubler current and AGC voltage), and/or step changes in frequency, which results in step phase changes of sufficient magnitude to unlock the ground receivers.

3. The changes in operating point appear similar to some experienced in downstream tests of several other serial numbered units which were corrected during repair and/or L. O. frequency change. This type of malfunction was related to thermal-mechanical problems with module-cover solder joints and module mounting, and should not appear in Flight 4 transmitters. This type of malfunction does not result in complete functional failure or a catastrophic failure such as high current drain.

4. The transmitter can be expected to remain functional (if its use is required) but may continue to cause receiver unlocking problems during temperature changes. Temporarily switching back to "A" could result in obtaining useful engineering data. From a purely operational point of view, switching to "A" may be desirable only if "B" becomes unusable.

DATA SOURCES AND INTERPRETATION

Data used in this study were obtained from two basic sources - MSC/MSFN ALSEP mission data and the Bendix preshipment test data. The first data reviewed consisted of selected mission printouts and reconstructed analog recordings. These sources covered the time periods in the immediate vicinity of some of the downlink anomalies. Some additional step changes in transmitter "A" AGC and doubler current were noted at periods when lock was lost. During other anomalous periods, lock was lost and the recorded values were meaningless. The short runs of data do not indicate which value is "normal" during the step changes. Long term trend data (AGC and doubler current vs temperature) can be used to establish the "normal" characteristic curves. Therefore, MSFN/ALSEP mission data from the real time coverage log, maintained by the BxA Thermophysics Group, were plotted for the AGC and doubler current vs temperature for the entire period of transmitter "A" operation. See Figures 1-6. These figures are plotted for each Lunar day to cover the range from minimum to maximum temperature.

Changes in operating points of the AGC voltage and doubler current may be seen to exist when the curves for the different days are compared. The period of these changes from the norm, sometimes persist for hours or days. The steps or deltas appear to be induced by temperature changes. When the temperature was stabilized, hot or cold, for a long period, the deltas usually did not occur except for the second night when 5-6°F temperature excursions resulted in 4 to 5 milliampere deltas in the doubler current. Normal change, over this temperature range, is approximately 1 milliampere.

Further comparison shows the spot checked values from the Vendor ADP, Bendix PIA and Thermal-Vacuum tests to have a noticeable scatter around the curves plotted from moon data. Vendor AT test points should perhaps not be considered since the transmitter was operating into slightly different VSWR loads. All Bendix tests were operated into the Diplexer Switch flown with the unit, although the PIA test was conducted during a different physical hookup. If system-only tests are compared with flight, it is seen that at Moon turn-on, the AGC tracked the test data while the doubler current started out low, but tracked the test data following the first lunar noon (except where the deltas occurred). AGC shows a small overall increase with time. Only approximately 15 minutes of data per stabilized Thermal-Vacuum condition is available for SN-12 since it was treated as the redundant transmitter during test. Temperature change induced deltas in operating characteristics are therefore not available during system test.

For a comparison, 1-1/2 lunar days of "B" transmitter (SN-14) data were plotted along with its ground test data. "B" shows excellent repetitive AGC tracking, but all at levels lower than test levels ($\simeq$ 0.1 volt lower). The doubler current shows levels slightly lower than test (2-3 mA) and excellent tracking except for two shifts of 5 mA each in operating points at approximately 30°F and 55°F on its first day of the climb from night to noon. The plotted data is shown on Figure 7.

Interpretation of the meaning of the apparent shifts is necessary. Shifts in operating modes have been seen in several transmitters during test and were shown to be temperature dependent. If, for example, the phenomenon is only a temperature induced tuning mode change in a multiplier circuit, and the jump is small, it is probably insignificant. However, all transmitters checked and repaired following the problems with EASEP transmitters SN-10 and 20 have been 100% tested over the temperature range; and to be acceptable, no deltas or shifts were permitted.

The more significant possibility with SN-12 is a problem unknown when Flight 1 was built and tested. The problem was discovered during in-house repair of transmitters SN-10, 16, 19 and 20. Thin-wall module covers, where soldered to the module bases, were found to crack with either handling or temperature cycling. The problem was apparently the consequence of the soldering method used which looked very neat but did not result in solder flow under and into the juncture. When these covers cracked loose, many peculiar symptoms occurred; such as modulation waveform distortion, modulation index change, step changes in AGC and doubler current (with temperature change) and downlink sync losses. Apparently, thermal-mechanical stresses were built up, and when relieved by slight shifting, altered the tuning in a step (or transient) manner and caused the malfunction symptoms. Similar thermal-mechanical stress-relief changes occurred occasionally in the output filter and AGC sense line causing fluctuations in the AGC voltage and output level.

Anything affecting the VSWR of the output also could cause similar changes in AGC and doubler current level, so the possibility of the connections between the diplexer switch and transmitter, or the switch itself cannot be completely ruled out. The reported frequency jumps, past test history and satisfactory operation of transmitter "B" minimize the switch possibility.

Another transmitter assembly problem was found during the in-house L. O. frequency changed and repair of a later SN transmitter. The hold-down screws used to attach the control-amplifier module to the base were toleranced for a possible interference fit. The sitiuation resulted in bottoming of one screw leaving the module attachment insecure. Slight mechanical or thermal induced mechanical movements caused a changed in the ground return path and hence the tuning. These minor transient detuning effects showed up as variations in the output and telemetry parameters and as "glitches" in the rf output.

The remote site monitoring stations reported frequency shifts of their VCOs equivalent to approximately 600 Hz at S-Band. However, received signal strength remained constant and a spectrum analyzer monitoring the ground receiver 50 mHz input showed no detectable anomalies. Excessive frequency or phase steps could easily unlock the ground station receivers. Certain step tuning changes, caused by the cracked module cover seams, could produce frequency and hence phase deltas, and/or shifts in operating modes. With the data available, it was not possible to correlate the frequency shift with the steps in AGC and doubler current at precise times. The sample rate prevents closer correlation than 54 seconds. Some anomalous periods show several frequency jumps in the same time span as several AGC and doubler telemetry deltas are seen. At other times, frequency jumps are listed, but the analog recording shows no AGC or doubler changes. Any relationship is inconclusive. The attached Figure 8 shows a plot of transmitter frequency test data versus temperature. Unfortunately there exists no continuous measurements. The Figure 8 shows 9 measurements (total) at different times and at stabilized temperatures. A portion of a typical "S" curve fits through the points fairly well, but 600 Hz deltas would never be detectable without many more points on the curve.

The 10 volt regulator within the transmitter is cleared of suspicion because the crystal temperature telemetry flawlessly tracks the heat sink temperature telemetry. The oscillator, modulator, and crystal temperature thermistor are all supplied by a common 10 volt regulator. The heat sink thermistor is powered directly from the +12 volt supply. Ten volt regulator problems should therefore show in the temperature telemetry unless strictly transient in nature.

SIGNIFICANCE OF THE ANOMALY

Obviously, transmitter "A" caused enough downlink problems to warrant switchover to transmitter "B". The anomaly or malfunction raises three basic questions:

1. Is transmitter "A" still "good" enough and safe enough to command on and use if "B" degrades?

2. Are similar problems possible with Flight 4?

3. How good is the testing philosophy and the data availability as pertains to remote troubleshooting efforts?

The following opinions are offered in answer to these questions:

1. If transmitter "B" were to fail completely, obviously "A" should be commanded on; however, in view of the mission objectives, as long as "B" is usable "B" should be left on. It is this writers opinion that "A" transmitter will probably operate satisfactorily at reasonably stabilized temperatures. The data received from the moon, and past experience from other transmitters provide reasonable confidence that the suspected form of malfunction will not result in excess current drain nor sudden total failure. Therefore, "A" could be safely commanded on.

2. The occurrence of a similar type of malfunction is very improbable on Serial No. 19 and 20 installed in Flight 4. Both transmitters were completely reworked, X-rayed, and known typical troublesome areas corrected. Both transmitters were monitored over the full temperature cycle during acceptance test and both were subjected to thermal-vacuum tests for component acceptance.

3. The data available from both the pre-shipment tests, and the reduced data from the ground stations provides the anticipated measuring capability of performance, but is too limited to provide detailed aid for remote trouble shooting. The first limitation is because of the small number (4) of transmitter parameters telemetered. Secondly, the frame rate providing one sample every 54 seconds makes it difficult to correlate transient phenomena between several parameters. And of course, if the transient is sufficient, receiver lock is lost and transient data is not available at all. Even with these built-in limitations, there exist several other more severe limitations to trouble shooting in the case of transmitter "A". Most of the component and subassembly tests, as performed when SN-12 was built and accepted, were of the static measurement type. That is; environmental conditions were stabilized and the pertinent parameters measured for conformance with specification values and tolerances. The later thermal vacuum systems tests provided only about 15-20 minute checks of the redundant transmitter "A" at stabilized environmental conditions. It was therefore not possible to determine if any temporary steps in the operating mode of the transmitter occurred prior to flight. Neither was it possible to draw curves to compare AGC voltage and doubler current versus temperature with the curves drawn from the data telemetered during lunar operation. Only the stabilized test points could be compared. Full range calibration curves would be very useful for this type of "downstream" trouble shooting.

More information could be gained and the interpretation of the data made easier if the ground station printouts and reconstructed analog recordings were to be changed slightly. All references, data and correspondence should be annotated in common standard GMT thus eliminating the time correlation problem. In plotting the parameter trends, the unprocessed telemetry voltages (such as the AGC) are more effective to work with than are the engineering conversions such as the doubler current printout. For example; it may be possible that some modest step occurs in the curve when the computer is programmed to compensate the data for a different temperature range. It is understood that there is a family of 5 compensating curves applied to the doubler parameter for the range between -10°F and +140°F. Additionally, the conversion curve from voltage to current is good only as long as no malfunction occurs. Therefore, in looking for malfunction trends, the decommutated non-processed voltage is best. A definite indication on all printouts, or recordings, as to whether loss of

3. (cont.)

sync has altered the data value is also imperative. Highly desirable, to eliminate time consuming manual comparison and plotting of data, would be computer plots of the data such as was manually done on figures 1 through 7. A computer plot could provide much higher resolution by plotting each satistically significant change in the parameter of interest versus temperature and annotating the plot with the time of each significant change. Thus an accurate trend line, or operating curve, could be plotted and step changes or deltas could be related within the 54 second resolution of the telemetry mainframe.

High resolution data obtained as above, would permit a much greater degree of confidence or refutation of the conclusions drawn as to the cause of the malfunction.

CONCLUSIONS

The conclusion drawn from the analysis of the available data indicates that the transmitter "A" can be safely operated, though for data purposes, it will probably remain "noisy" during periods of temperature transition. From an engineering point of view, it would be very informative to command transmitter "A" on for several hours, at about the same time of Lunar day and temperature as existed prior to its shutdown. In addition, an on-period of several hours at stabilized hot and cold extremes would be useful for comparisons. Data obtained should be made available for analysis, in analog form with mainframe time correlation marks, and also in "Delog" printout. Any sync losses should be time correlated. X-Y plots, as referred to earlier, would be extremely useful.

From an operational point of view, there is sagacity in assuming a "leave it as it is" philosophy. The system, with Xmtr "B", functions well and the operational need to return to Xmtr "A" may never occur. If Xmtr "B" were to degrade, and if a period of scientific interest were in progress, then better knowledge of the condition of Xmtr "A" would allow firmer timing in an operational decision as to when to switch back to Xmtr "A".

LIST OF SOURCE MATERIAL

1. Delog EGMT D-364 H-19 M-16 S-00
   to EGMT D-002 H-19 M-35 S-57

2. Delog EGMT D-361 H-09 M-04 S-02
   to EGMT D-363 H-21 M-17 S-58

3. High speed engineering and science data printout

   GMT 031/02/27/48
   to 031/03/59/02

   GMT 031/03/00/51
   to 031/03/59/43

   GMT 031/04/01/31
   to 031/04/49/42

4. Analog strip charts

   GMT 030/22/00/00
   to 031/05/00/00

5. Vendor ADP for Xmtr SN-12 and 14

6. Bendix TP2333090 Pre-Integration test procedure for Xmtr SN-12

7. Tape replays for Flight 1 Thermal-Vacuum test and recorded parameters per TP2333032

8. Tape replays for Flight 1 system and stowed configuration recalibration per TP2333034 and TP2338600

EXPLANATION OF FIGURES 1-8

Figures 1-6 show the full 3 Lunar days of transmitter "A" operation. Each figure has the pre-delivery spot check values of AGC voltage and doubler current pinpointed and annotated with a date and test name abbreviation. AGC is plotted as voltage vs. temperature and the doubler current is plotted as current in mA vs. temperature. The circled dots represent component and system level test check points. The associated numbers represent the calendar dates of the tests.

The nomenclature is as follows:

PIA	Pre-Integration Acceptance Test
Vendor AT	Vendor Acceptance Test
T/V	Thermal Vacuum Test
Recal	Recalibration Test Prior to Shipment.

The curves are plotted from the reduced telemetered downlink data. The day and hour is annotated at selected points along the curves.

Fig 1 Starts at turn-on at 323-1423 and 59^{o}F and is plotted through Lunar noon at 333-0200.

Fig 2 Starts at Lunar noon at 333-0200 and is plotted to the left on the page until the coldest point at Lunar night is reached at 339-3300.

Fig 3 The heaters were turned on at approximately 339-3300 and the temperature rose to 24.5^{o}F where it was stabilized for 11 days within $\pm$ 1 bit. During the increase between 10^{o} and 20^{o}F, the doubler current showed approximately 6 mA deltas. The curves are plotted to the right until the highest temperature of the 2nd Lunar day is reached at 361-1900 (98.6^{o}F).

Fig 4 The plot starts at 361-1900 of the 2nd day and is plotted to the left. At 87^{o} to 83^{o}F small deltas are seen in both the AGC voltage and the doubler current. At 42^{o} to 40^{o}F a step change in doubler current is seen. During the cold Lunar night period at approximately 23^{o} to 28^{o}F (the stabilization range) the doubler current can be seen to be jumping between two levels as projected by two segments of the curve. The plot stops at 016-2300 of the 2nd Lunar night.

Fig 5 The plot starts at 016-2200 of the 2nd Lunar night and is plotted to the right until noon of the 3rd Lunar day at 024-1657. Deltas in both AGC and doubler current may be observed between 45^{o} and 56^{o}F. It should be noted that the entire 3rd day doubler current curve runs higher than the 1st day's curve.

Fig 6 The plot starts at 024-1657 and is plotted to the left until transmitter switch-over at 53^{o}F and time 031-03-56-11. Just prior to switchover, relatively large deltas occurred in both the AGC voltage (0. 16 volts) and the doubler current (18ma). These deltas are larger than those previously seen.

Fig 7 One and a half Lunar days of data are plotted on this Figure. Transmitter "B" was turned on at approximately 53^{o}F and 031-03-56-11. The AGC shows excellent repetitive tracking over the day and a half. The doubler current shows a step in level of 5mA during the 1st return from Lunar night at approximately 30^{o}F. Another step, back down, then up again occurs at 55^{o} to 59^{o}F. Following that, the doubler current tracks repetitively.

Fig 8 Figure 8 shows a plot of the frequency vs. temperature measurements made during test. A portion of a typical S-curve fits fairly well through the points. These are too few points to provide sufficient accuracy to determine if any of the points could have shifted to the 600 Hz from the norm as reported by the downlink receivers.

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. 46 1513 MADE IN U.S.A.
KEUFFEL & ESSER CO.

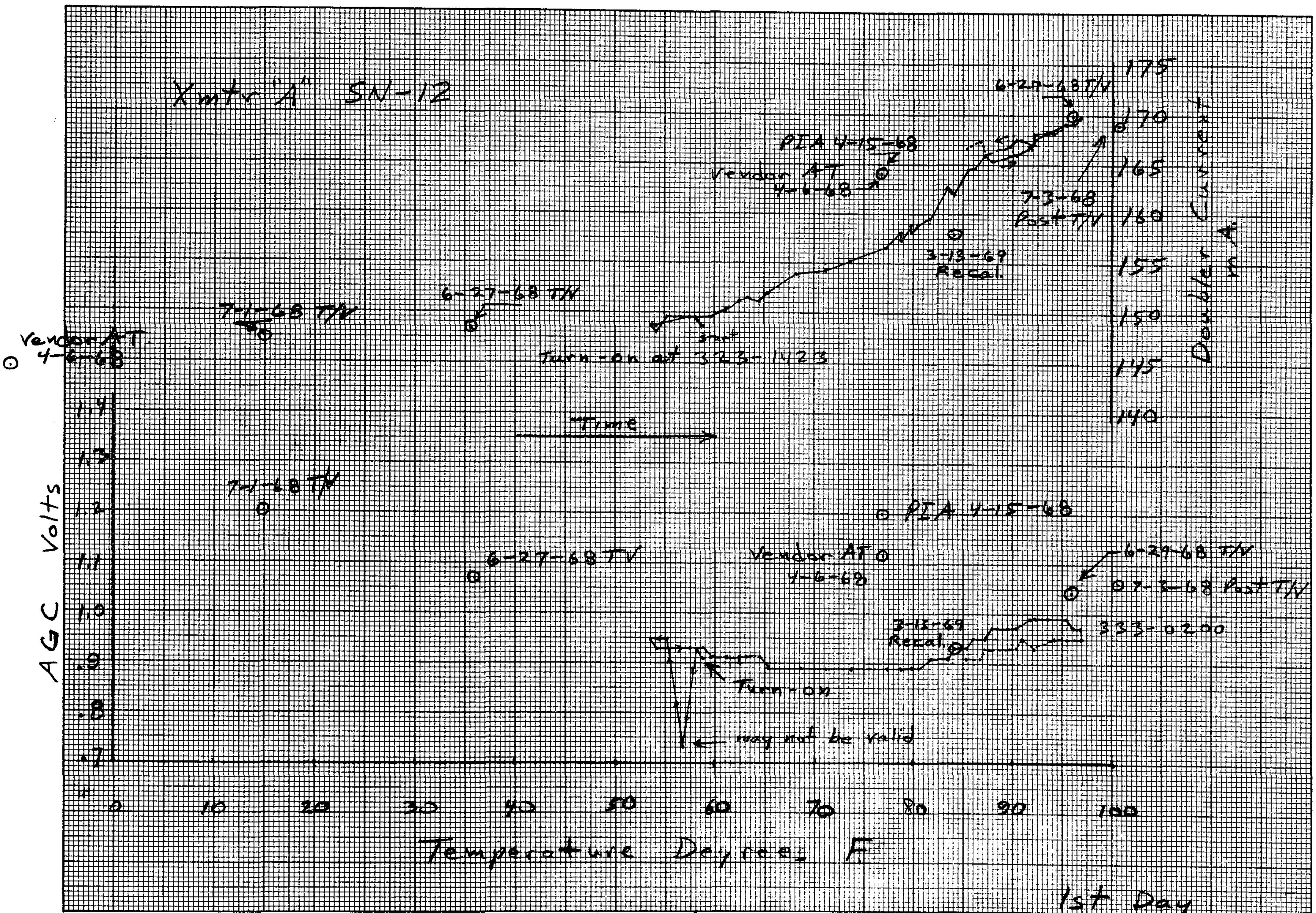

Fig 1

K+E 10 X 10 TO THE CENTIMETER 46 1513
18 X 25 CM MADE IN U.S.A.
KEUFFEL & ESSER CO.

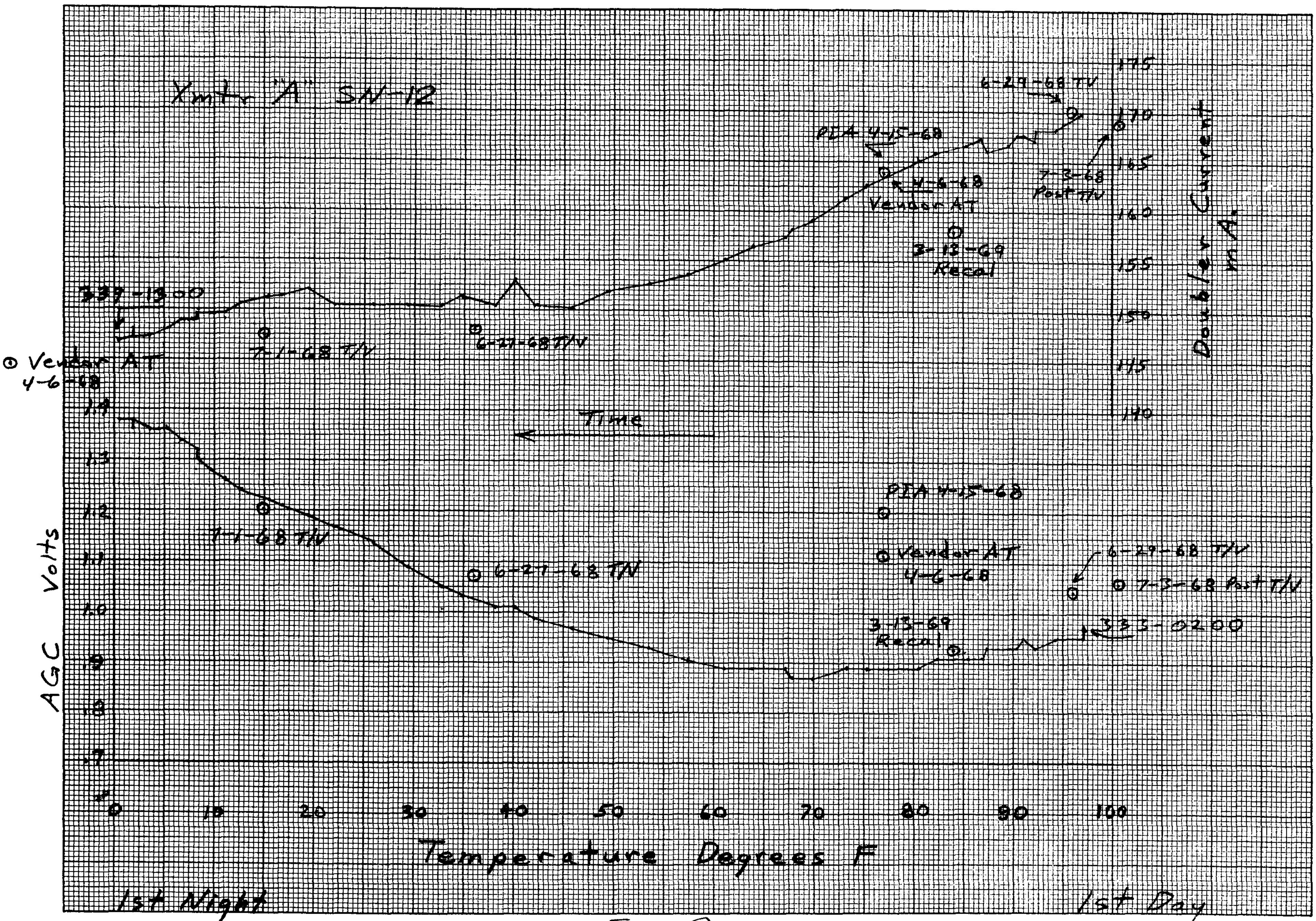

Fig. 2

K+E 10 X 10 TO THE CENTIMETER 46 1513
18 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

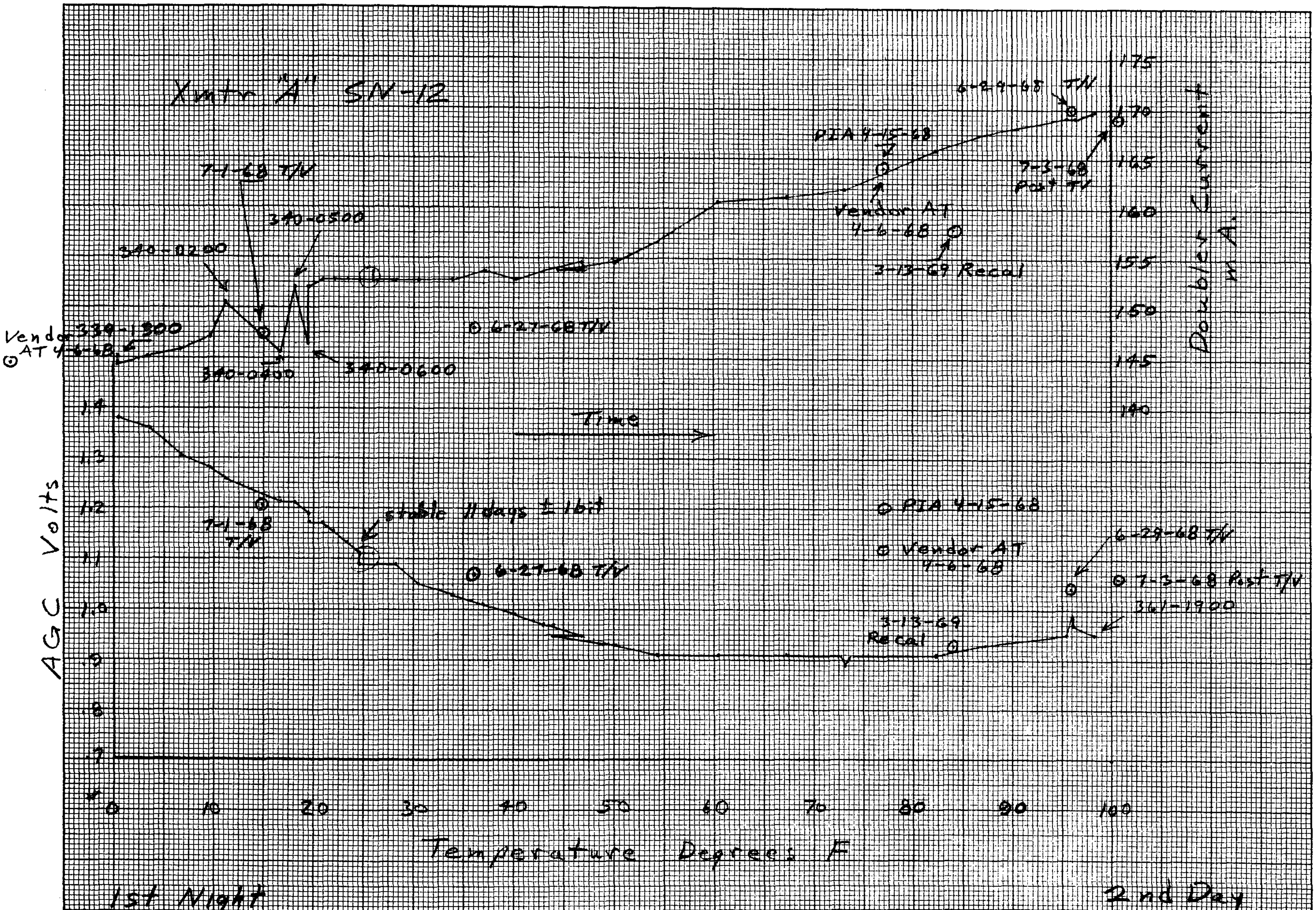

Fig. 3

K+E 10 X 10 TO THE CENTIMETER 46 1513
18 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

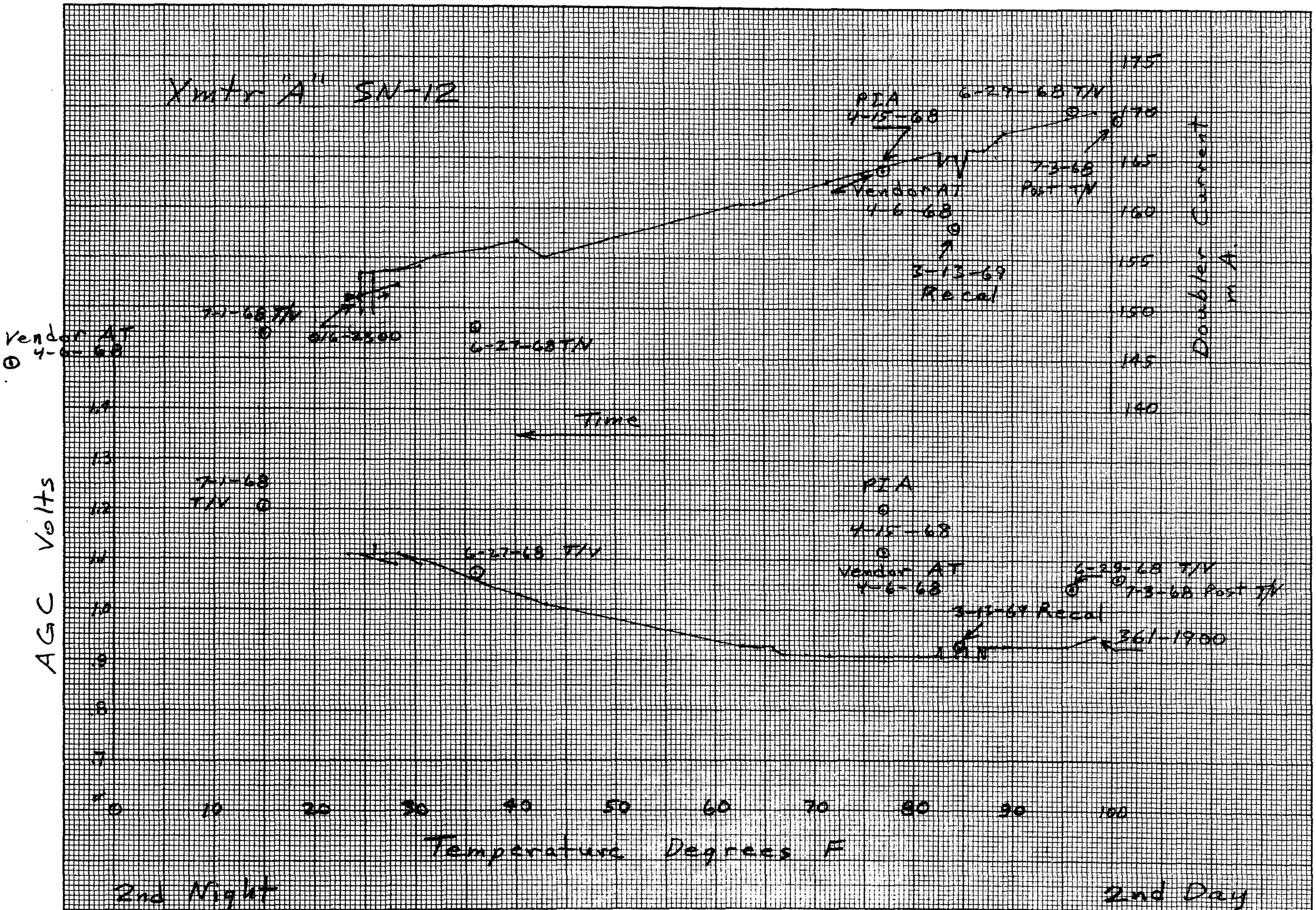

Fig 4

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. 46 1513 MADE IN U.S.A.
KEUFFEL & ESSER CO.

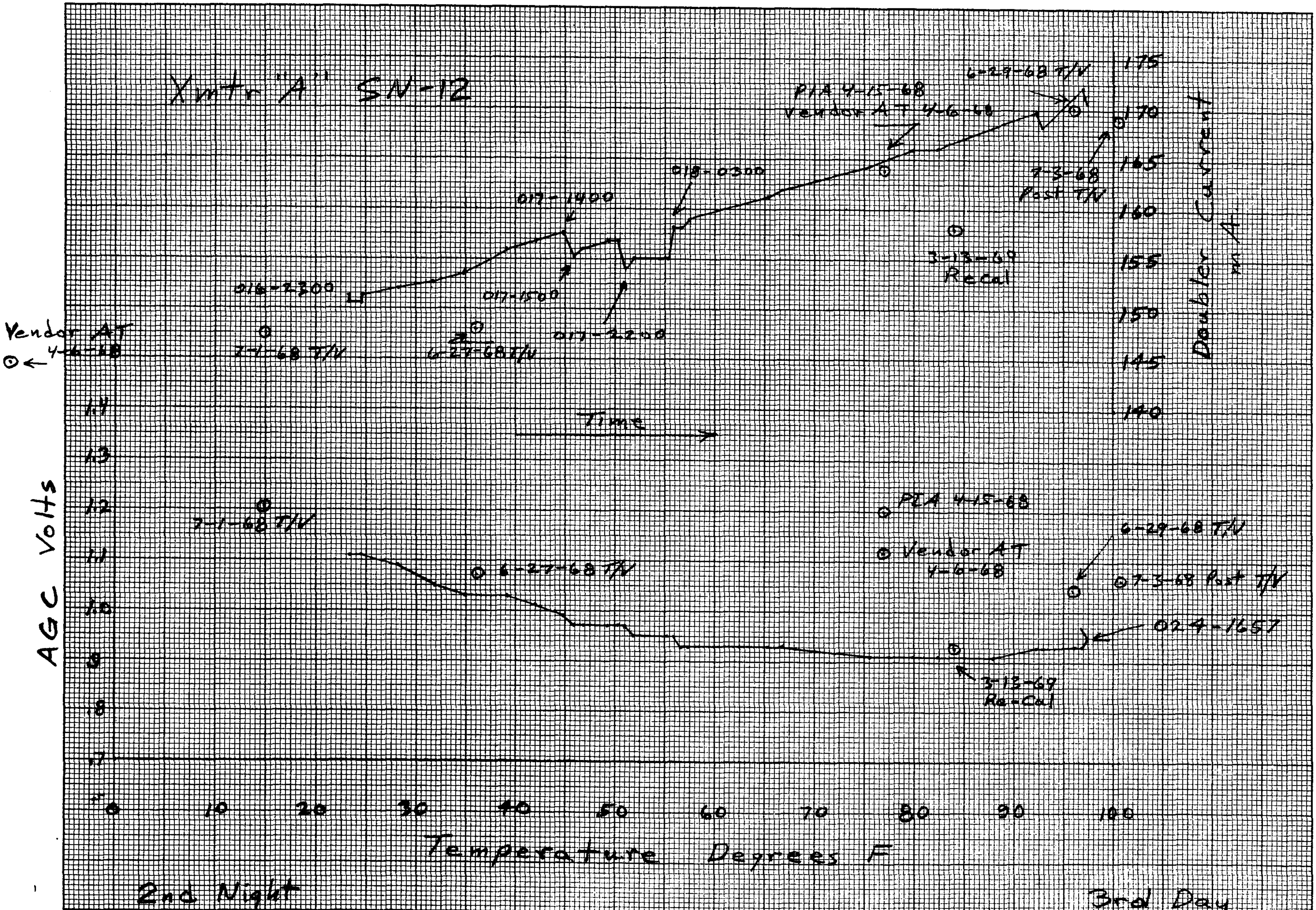

Fig 5

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. 46 1513 MADE IN U.S.A. KEUFFEL & ESSER CO.

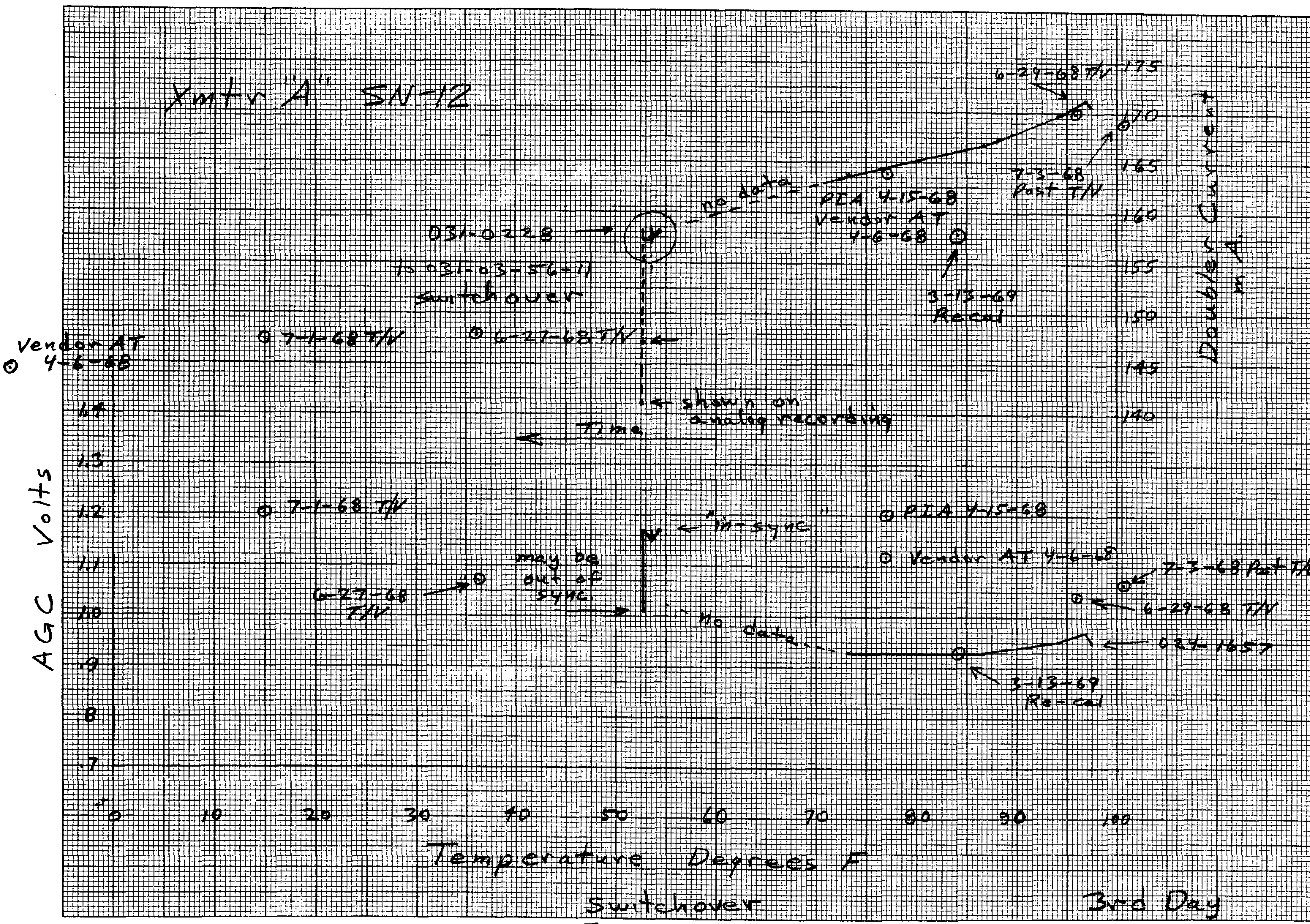

Fig 6

K+E 10 X 10 TO THE CENTIMETER 46 1513
18 X 25 CM. MADE IN U.S.A.
KEUFFEL & ESSER CO.

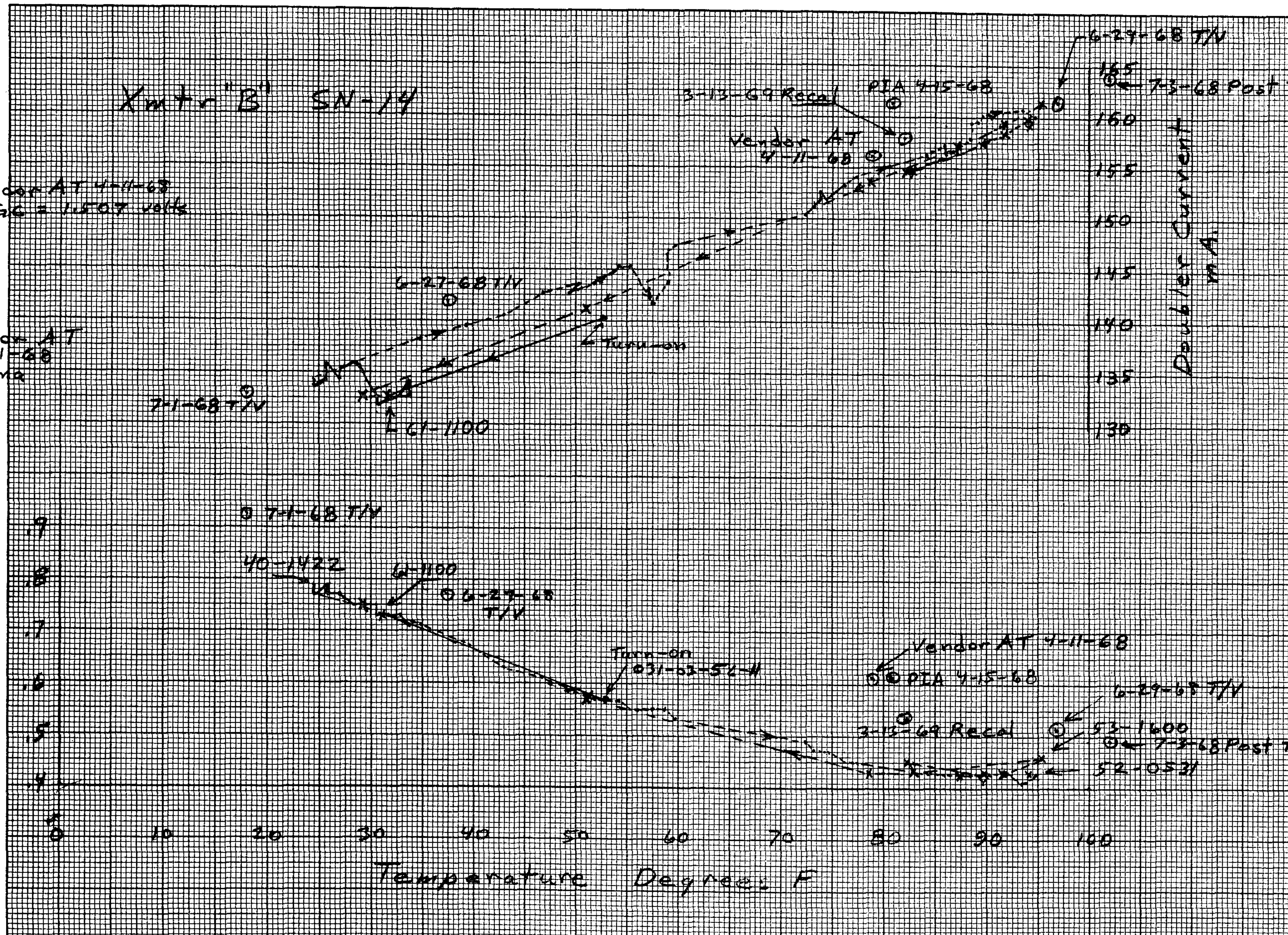

Fig 7

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. 46 1513 MADE IN U.S.A.
KEUFFEL & ESSER CO.

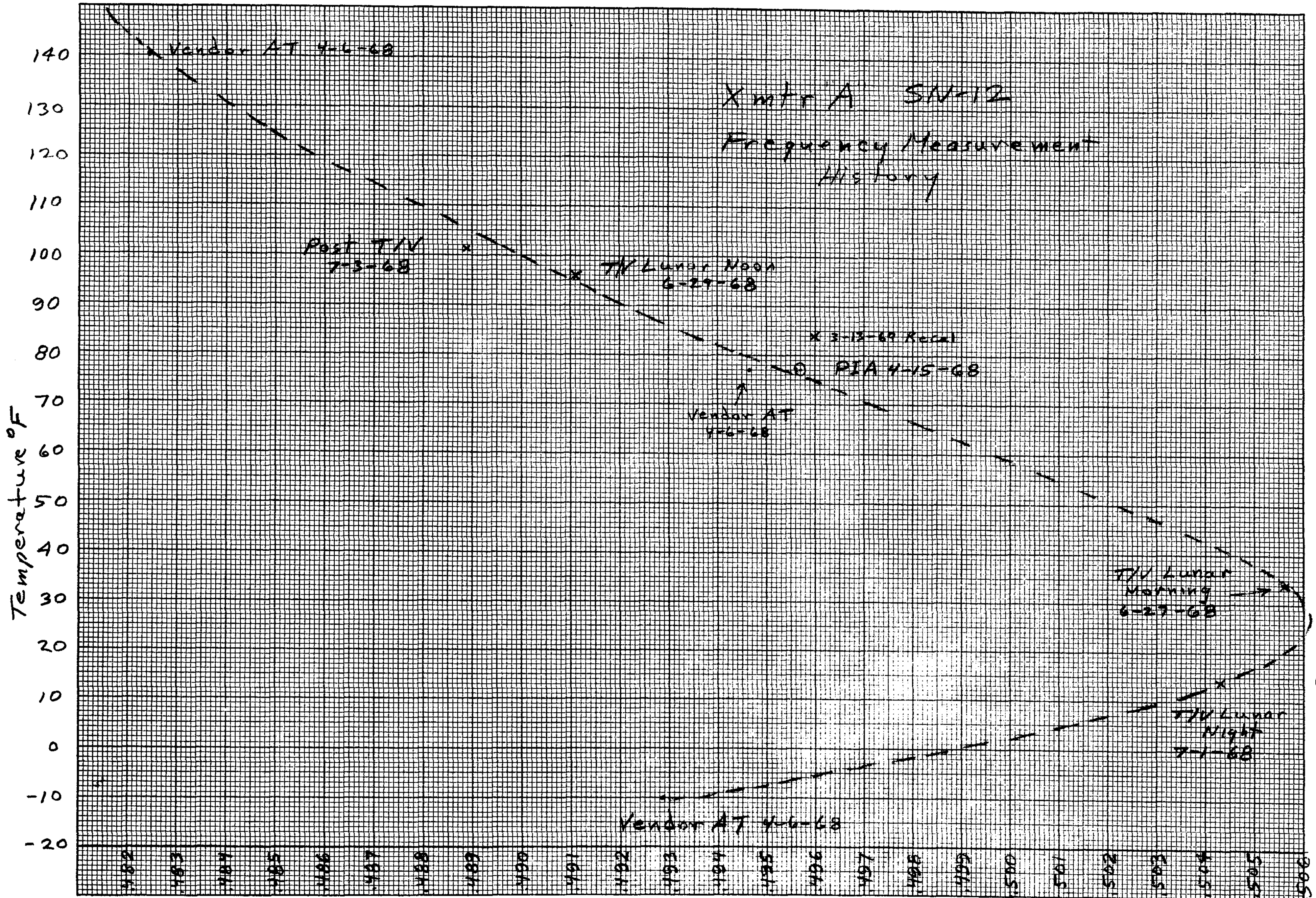

Fig 8 Frequency Meg Hertz