NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

November 13, 1989

MEMORANDUM:

TO: M. Balister, J. Cochran, D. Emerson, P. Jewell, J. Kingsley, J. Lamb, A. Perfetto

FROM: J. Payne

SUBJECT: Tests of 12-m 4 K System in Green Bank

Introduction

Jack Cochran and I have recently completed a series of tests on the 4 K system intended for use on the 12-m telescope.

The system tested was the large, stainless steel dewar that I have described several times in Tucson. It has space for 8 millimeter-wave insert receivers and is equipped with a 4 K refrigerator of nominal 1 W capacity. For the tests it was equipped with two 230 GHz insert receivers that had recently been tested in Charlottesville. Care was taken to use the same temperature sensors and readout for both tests so that true comparisons could be made. The main points of interest were as follows:

1) Is the cool down time satisfactory?

2) What is the reserve capacity of the refrigerator system when driving two inserts?

3) What is the operating temperature of the inserts?

4) Could we operate the system at reduced pressure in the return line to operate at below 4.2 K to possibly increase the performance of the receivers?

Cool Down Time

The cool down of the system is shown in the attached figure. As a reminder: the first stage of the refrigeration system drives the main radiation shield and the first J-T cooler and runs at nominally 60 K, the second stage runs the second J-T cooler and nominally runs at 12-13 K, and the mixer is attached to the third stage and runs at around 5 K.

The total cool down time is 14 hours. This may seem long when compared with the existing Tucson systems, but it is actually short when compared with existing 4 K systems. The Green Bank maser system takes 40 hours to cool (with no pre-cool), and the 4 K system intended for use on the VLBA took 36 hours to cool with no load. A major reason for the long cool down time is the high thermal resistance of the hydrogen switch connecting the mixer and the second stage. This is evident from the cool down curves as it may be seen that the second stage cools rapidly to below 20 K. A mechanical switch instead of the hydrogen switch would undoubtedly reduce the cool down time appreciably.

The cool down time may also be reduced by adding a nitrogen pre-cool to the third stage. We have had the Green Bank shop build the necessary components, and we can add these in the future. For the moment, I feel it is far more important to get the system on the telescope.

Reserve Capacity

The system cooled satisfactorily to around 4.7 K, and we then loaded the refrigerator by means of a resistor attached to the third stage. The method used was to steadily increase the load on the refrigerator until the temperature of the third stage continued to increase at that particular load level. The load was applied in 100 mW increments, allowing about 10 minutes between increments. The capacity of the refrigerator had been previously measured with no inserts attached and a result of 1.1 W was obtained. We measured an identical result with the inserts attached - the implication being that the inserts have negligible load. We should do more careful measurements in the future, but it seems that a pair of inserts take less than 10% of the refrigerator capacity. The HEMT amplifiers were off for this test, and the infrared windows were not installed, so the loading in actual use will be more than that measured in these tests. We have measured the load from both these sources in the test dewar on a single insert and although the infrared filters need improvement, there should be no problem handling the extra load from both these sources.

Operating Temperature

The noise temperatures of the two inserts were measured at a physical temperature of 5 K. Noise temperatures of 124 K DSB for insert (1) and 150 K DSB for insert (2) at 230 GHz and around 110 K DSB at 200 GHz for both were measured. Pan has measured the dependence of noise temperature on physical temperature, and below 4.4 K we don't gain much. From 5 K to 4.4 K we should gain 10-15 K (DSB) on the noise temperature so any temperature gain below 5 K to 4.4 K is worth pursuing. The physical temperature of both mixers in the test was 4.77 K. This can be expected to increase slightly with the addition of power to the HEMT amplifiers but will still be below the 5 K of the noise temperature measurements.

Operation at Reduced Return Pressure

It is possible to operate the compressor driving the J-T valve with reduced pressure in the return line and so reduce the operating temperature of the

refrigerator. The system developed by Larry D'Addario, for example, operated with a negative pressure of around 24 inches of mercury (these are the units that are used) on the return line and ran at a temperature of around 3 K.

In our tests, we were only able to reduce the return pressure to about -3 inches of mercury. This reduced the mixer temperature from 4.77 K to 4.49 K. An error has been made in the design of the compressor; I will have this corrected in the next couple of months. The compressor operates very reliably with normal (i.e., atmospheric pressure) in the return line, and I see no reason to delay telescope installation.

Calibration of Tucson Readout/Charlottesville Readout

In order to eliminate any doubt on the calibration of the temperature measuring instruments, I asked James to send the Tucson instrument to me in Green Bank. We were then able to connect the Tucson box to the sensor on the mixer.

Temperature with Charlottesville readout = 4.49 K
Temperature with Tucson readout = 4.52 K

The difference of 0.03 K is quite acceptable.

Conclusions

The dewar and inserts perform well. There are numerous small improvements that can be made, but I believe our top priority should be to put the system on the telescope as soon as possible. The two major remaining tasks that need to be done on the cryogenic/optics package are as follows:

1) Design of a suitable polarization diplexer

2) Design of a backshort servo

For (1) we can use the crossed grid diplexer that has already been built plus a couple of 45° mirrors. This is a minor job on which the Green Bank shop is working. (2) will take someone a couple of days to design.

The Next Month

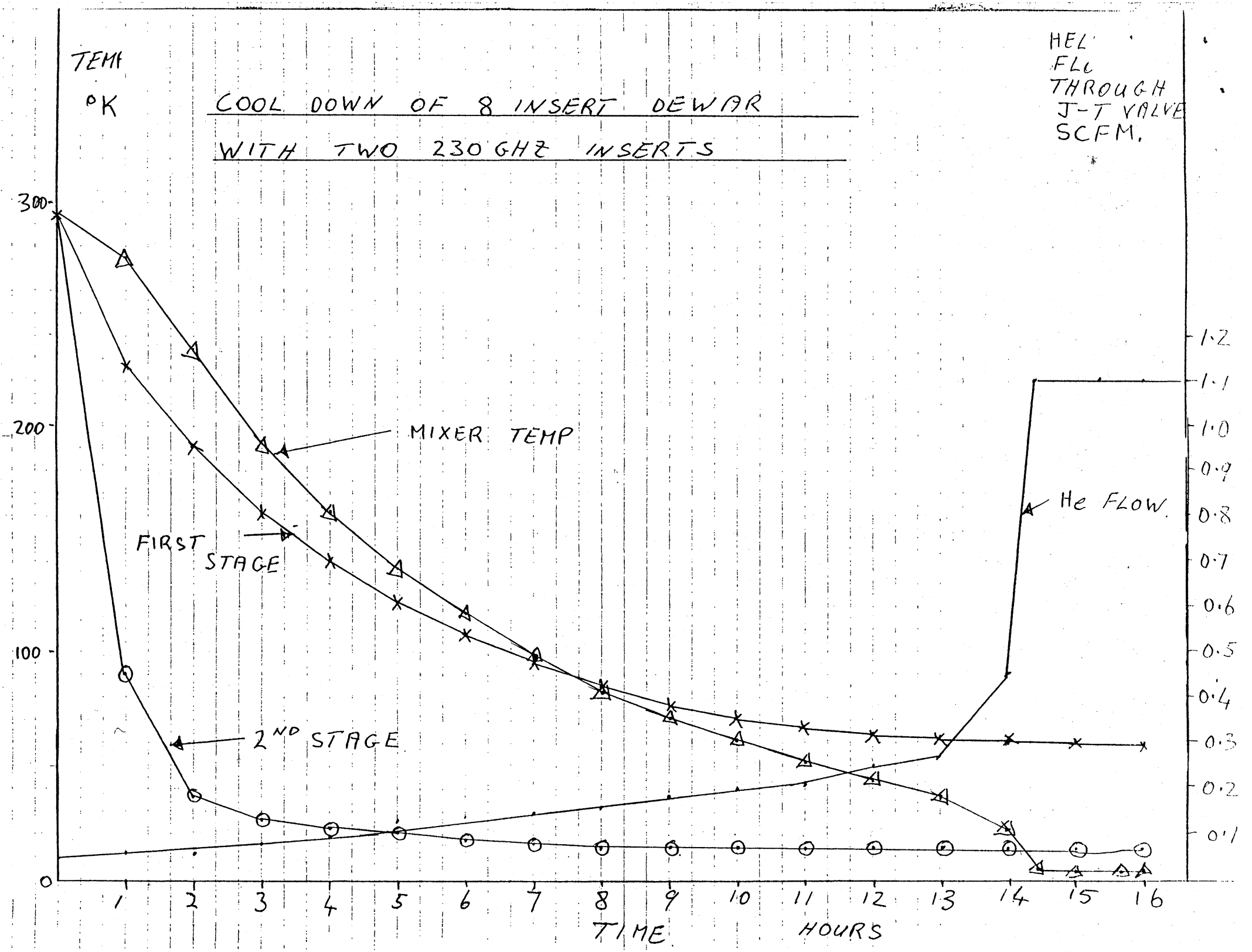
1) Everything will be shipped to Tucson on November 14.

2) Dave Williams will go to Tucson to help Jack set up the cryogenics. I will discuss with Jack and Dave the details of what needs to be done.

3) John will go out to Tucson around November 28th to help set up the dewar and to do initial tests.

4) Tony has designed a modified mixer that should give better performance at 230 GHz. We hope for < 100 K DSB.

We probably need to get together for a telephone meeting during the week of November 20th. I will firm up this.


TEMP
°K
COOL DOWN OF 8 INSERT DEWAR
WITH TWO 230 GHZ INSERTS
HEL FLO THROUGH J-T VALVE SCFM.
300
200
100
0
MIXER TEMP
FIRST STAGE
2ND STAGE
He FLOW
1·2
1·1
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
TIME
HOURS