ANNEX 15

COOLER SYSTEM USER'S MANUAL

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CONFIGURATION MANAGEMENT
Astrium Ltd
(STEVENAGE)
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INTEGRAL

COOLER SYSTEM USER MANUAL

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1. INTRODUCTION

The purpose of this User Manual is to allow personnel to operate the INTEGRAL Cooler System in its various modes without causing damage to any part of the system. To this end, operational constraints are highlighted and a telecommand (TC) listing given which show the maximum compressor piston amplitudes allowed in order to avoid compressor damage. These upper limits must not be exceeded and therefore each CDE is adjusted on test to suit a particular compressor power. Telecommands for a particular power may vary between different CDE/Compressor pairs, and damage may result if the telecommand for the wrong pair is used.

The command sequence to obtain the various modes and compressor piston amplitudes are discussed, together with the procedure for reducing the stroke amplitude at eclipse entry and for stopping the movement of the pistons when desired.

This document applies to the Flight Cooler System (CDEs, SPICO and cables as supplied by Astrium), unless specified differently.

A Calibration table is included which shows the individual telecommands required and telemetry expected for the relevant stroke lengths for each FM Compressors.

As part of the Performance Tables, the amplitude of the demand signals (AC Telemetry) and the associated drive levels (DC Telemetry)) for each FM compressor are given, together with the cryo temperature reached for each stroke.

Recovery procedures in case of failures are also given together with the relevant parameter to be monitored in order to isolate the problem.

In this Manual the bit convention used is that of the ESA Standard (ie B0 = MSB, B15 = LSB).

2. REFERENCE DOCUMENTS

The following documents form a part of this user manual to the extent specified here in. In the event of conflict between this procedure and the documents given below, then this shall be notified to ASTRIUM UK for resolution.

RD 1	IC2E101	ECL 08	GA CDE Control Drive Electronics (BOM)
RD 2	INT.ICD.CDE.0017.MMB	Issue 8	Cooler Drive Electronics Interface Control Document
RD 3	INT.DES.CDE.0040.MMB	Issue 5	Integral Cooler Drive Electronics Design Report
RD 4	INT-MAN-CDE-0041-MMB	Issue 6	Integral Cooler Drive Electronics (CDE) Handbook
RD 5	Integral EID-Part A	Issue 1 Rev 7	Integral Experiment Interface document 'for Instruments'

3. CONSTRAINTS AND WARNINGS

A number of constraints and warnings regarding the operation of the cooler system are given in this document and are repeated in this section for convenience:

3.1 Ground and Flight Constraints

- Never switch the relay between LCL modes when the coolers are active or when power is applied to the CDE. (See Section 8.1)
- Never start the Compressors at high amplitude levels but progress towards that level in steps. (See Section 11.2)
- Never go from maximum stroke to zero stroke in one Telecommand but reduce the amplitude of the compressor in steps. A sudden removal of CDE power is NOT recommended. (See Section 11.3)

3.2 Ground Constraints

- The calibration Tables give current and power data for the Astrium set up only. These two parameters maybe different in other configurations. Do not be tempted to send telecommands to get these correct and ignore the Telemetry for the drive.
- The Telemetry (demand, drive, and temperature) will always be correct irrespective of configuration (ie current and power readings).

Note: It is recommended that FM1 CDE is connected to Coolers A & B (see Fig 1).

4. DESCRIPTION OF THE COOLER SYSTEM

The International Gamma Ray Astrophysics Laboratory is an instrument used for Gamma Ray Astronomy. The detectors which perform the high energy Gamma ray measurements require cooling to 85 K for optimum detection. This cooling task is performed by the INTEGRAL cooler system.

The INTEGRAL Cooler System consists of four 50-80 K Sterling Cycle Coolers which are controlled by two electronic units. Each Stirling Cycle Cooler comprises one Compressor and one Displacer. The Coolers are mounted on a structure in pairs with the compressor and Displacer axial aligned to allow vibration cancellation to take place when they are operating together. This configuration results in the minimum microvibration environment.

The four Displacers are coupled by flexible thermal links to a common interface (H Block). This interface connects to the instrument detector assembly via a beryllium rod.

Each pair of Coolers is controlled by a separate Cooler Drive Electronics (CDE) unit. In order for the cooler system to operate, pistons within the mechanisms are fed with AC power at 43.42 Hz derived in each of the two CDEs. This power from the spacecraft has a separate bus, containing a Latching Current Limiter (LCL), for each compressor.

The cryo temperature reached depends on the amplitude of the movement of the pistons within the mechanisms. This movement is preset at +/-1.7 mm for the displacers but is telecommandable for the compressors. Indication of the piston amplitude and Compressor/Displacer temperature reached is provided via telemetry.

The larger the piston movement, the greater the mean input power taken from the bus. Since the mechanisms operate at a low frequency there is a large AC ripple superimposed on the input bus. If the two CDEs are operating in phase this ripple increases in an additive manner. The CDE provides the means to synchronise the output drive waveforms of each CDE at 90 degrees to each other, and in this way the peak current taken from the power bus is minimised. A block diagram of the arrangement is shown in Figure 1.

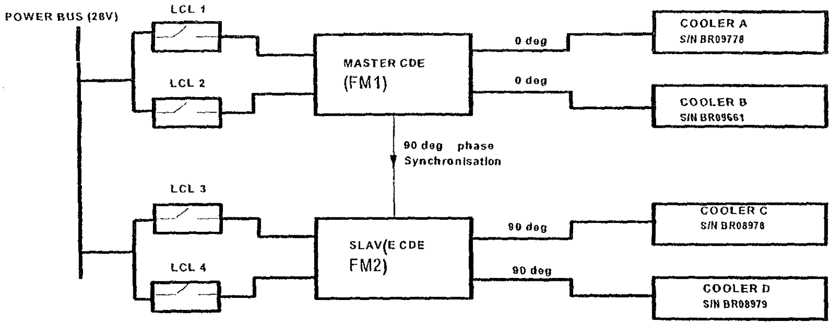


Figure 1 Diagram of Cooler System Showing Synchronisation

Note: Phase between

Comp A & B 0° SPI 1
Comp C & D 0° SPI 2

SPI 1 to SPI 2 90°
DISPLACER TO COMPRESSOR 68°

5. DESCRIPTION OF CDE INTERFACES

5.1 General

Figure 2 shows a block schematic of the CDE. It shows the main external interfaces; these being the telecommand, telemetry and power interfaces. The test points are used by Astrium during ground testing and cannot be accessed during flight. The Drive outputs are connected to the mechanisms and their position is monitored by the position pickoffs PPOs. The desired position of the mechanism pistons is controlled by feeding the PPO outputs back to the control loop circuitry.

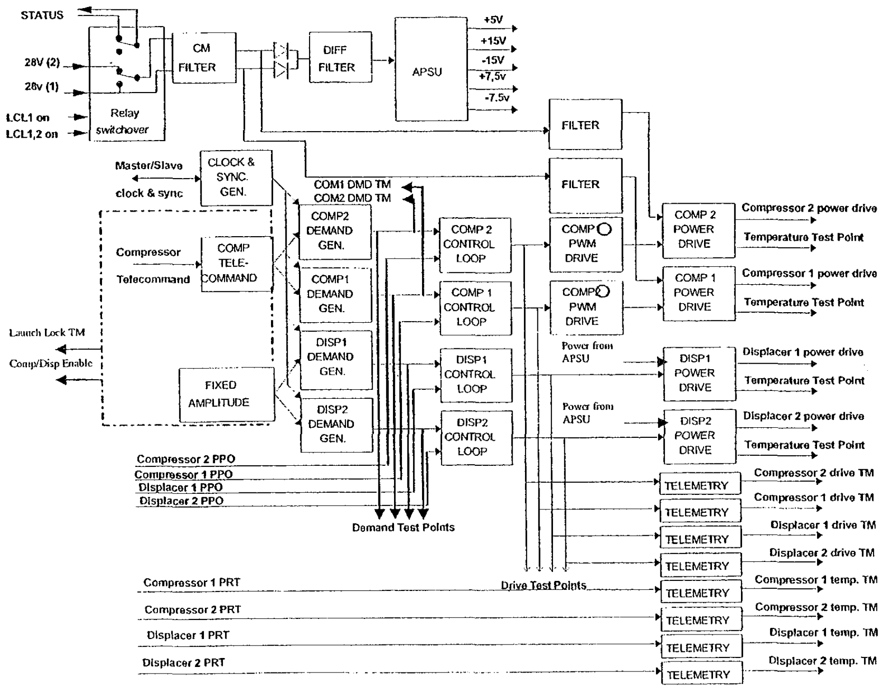


Figure 2 Block Schematic of CDE

5.2 Telecommand

The CDE is controlled by a single 16 bit serial telecommand which determines the System Modes of operation, and two High Level telecommands to switch the relay which determines which power bus is to be used (See below).

In the serial telecommand the Most Significant Bit (MSB) is transmitted to the CDE first. This is designated B0. The last bit transmitted (LSB) is designated B15.

Upon power-up all telecommand bits are initialised to 0. The telecommand operation is described in detail in Section 10.

5.3 Telemetry

Each CDE provides ten analogue telemetry channels, two digital channels and one Relay status channel. The analogue channels comprise four temperature monitors for monitoring the body temperature of the mechanisms, two compressor drive amplifier monitors, two displacer drive amplifier monitors and the two Compressor demand monitors. The displacer and compressor drive monitors provide indirect information about the piston position and are used in conjunction with calibration tables. Telemetry for determining the compressor demand is provided so that the phase between two CDEs can be determined. The digital channels provide information on the Launch Lock status and conformation of whether the compressors and displacers are enabled.

An additional monitor for each CDE provides the relay status which indicates the power routing from the power bus (ie LCL1 or LCL1/2).

The telemetry and monitoring is described fully in Section 12.

5.4 Power Interface

The spacecraft power is fed to each CDE from two buses, each containing a latching current limiter (LCL) and a relay. Power is then fed via separate internal buses to each Compressor drive stage. These separate buses are also diode OR'ed to provide another bus which feeds the integral APSU. This APSU generates the +/-15 V and +/-7.5 V voltages located within the CDE.

The Power Interface and operation of the relay is described in Section 8.

6. OVERALL CDE INTEGRATION

The Cooler mechanisms are delivered with fixed length drive cables and position pick-off (PPO) cables permanently attached to the corresponding mechanism. Each Compressor/Displacer pair is labelled as either A, B, C, or D and these letters are displayed on each of the cables together with the cable function. For example the position feedback cable coming from compressor B would be marked 'COMP B PPO'.

Every connector on each CDE is labelled as shown in Figure 3 below. The 'J' numbers are related to the Astrium test harnesses that are connected to them.

Each connector has another designator relating to its function and whether it is either a plug (eg PL1) or a socket (eg SK2).

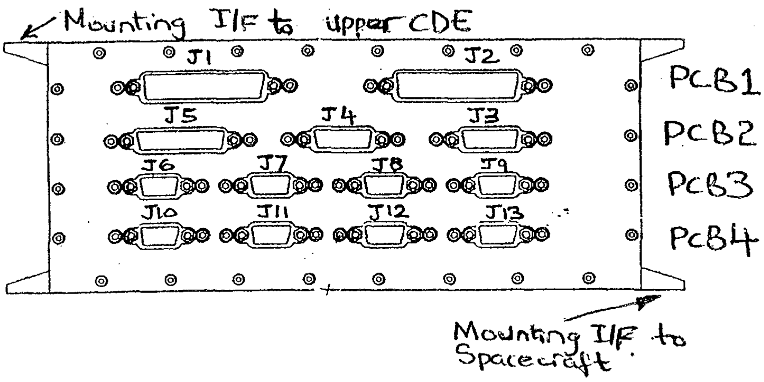


Figure 3 CDE Unit Configuration

A full listing of the connector function, designators, part numbers etc. is given in the next section.

The bottom two modules are associated with the fixed cables from the mechanisms.

Module 3 is designated for use with either the A or the C pair of mechanisms while Module 4 is designated for the B or D pair. With reference to the Connector listing below, the 'COMP B PPO' cable discussed above for example would be plugged into the J11 connector, since J11 is the Compressor B PPO input.

The top two modules are for connecting cables which come from destinations outside the cooler system. For example, J3 is the external power cable and provides the +28 V power to the CDE via the two external LCLs.

Note 1: ENSURE BEFORE OPERATION, J2 has either a TEST PERSONALITY CONNECTOR or the FM SYNCH CABLE C062911 attached. (When using the stacked CDE pair or single CDE's)

Note 2: In the Flight two CDE configuration the top CDE is inverted. (See INT-DES-CDE-0040-MMB Fig 11)

7. CONNECTOR LISTINGS

The Integral Cooler Drive Electronics has the following external connectors as defined in the table below. All connectors are of 'Cannon D' type, The 'Part' column below refers to the Cannon part number.

Table 1 CDE External Connectors

Name	Location	Type	Pins	Part	Description
J1 / PL1	Module 1	Plug	50	DDM-50P-NMB-1AON	Spacecraft telecommand ML
J2 / SK1	Module 1	Skt	50	DDM-50S-NMB-1AON	Synch Cable C062911 or TestPersonality connector
J3 / PL2	Module 2	Plug	15	DAM-15P-NMB-1AON	Spacecraft 28V power intake
J4 / SK2	Module 2	Skt	15	DAM-15S-NMB-1AON	Analogue telemetry to spacecraft
J5 / SK3	Module 2	Skt	25	DBM-25S-NMB-1AON	PRT connector + Comp PPO Connector
J6 / PL3A	Module 3	Plug	9	DEM-9P-NMB-1AON	Compressor Drive connector (A/C)
J7 / SK4A	Module 3	Skt	9	DEM-9S-NMB-1AON	Compressor PPO connector (A/C)
J8 / PL4A	Module 3	Plug	9	DEM-9P-NMB-1AON	Displacer Drive connector (A/C)
J9 / SK5A	Module 3	Skt	9	DEM-9S-NMB-1AON	Displacer PPO connector (A/C)
J10 / PL3B	Module 4	Plug	9	DEM-9P-NMB-1AON	Compressor Drive connector (B/D)
J11 / SK4B	Module 4	Skt	9	DEM-9S-NMB-1AON	Compressor PPO connector (B/D)
J12 / PL4B	Module 4	Plug	9	DEM-9P-NMB-1AON	Displacer Drive connector (B/D)
J13 / SK5B	Module 4	Skt	9	DEM-9S-NMB-1AON	Displacer PPO connector (B/D)

8. POWER INTERFACE

The power to the CDE (J3) is fed from two busses each containing a latching current limiter (LCL). Each bus voltage is nominally set at 28 volts and the current to the CDE is determined, amongst other things, by the compressor power that is required to give the desired cooling at the applied heat lift. The unit has a negative incremental impedance so that if the input voltage falls below 28 volts the input current increases. It should be noted that at high power loads, the input current can be large (in the order of 5 Amps) and is made up of a DC component and a large ripple component at 86.84 Hz. Hence, the power bus to the CDE must have a low impedance so that any reduction in the 28 Volts is minimised when the CDE is feeding full power to the compressors.

The CDE can operate from one or both of the 28 volt buses by applying high power telecommands to a latching relay. The configuration chosen depends on whether the cooler system is operating in the nominal mode, launch lock mode or backup mode.

8.1 Relay Operation

The relay is a 12 Volt EL 215 relay and control of the contacts is by high power telecommand (see). In one configuration the contacts are configured such that power via LCL1 feeds both Compressor 1 and Compressor 2. This configuration is intended for use when the cooler is operating in the Nominal mode. The other configuration allows power to be fed from each LCL. In this latter case LCL1 feeds power to Compressor 1 and LCL2 feeds power to Compressor 2. This configuration is intended to be used in the Launch Lock mode and the Backup Mode. (See also Section 18).

The relay configuration chosen is determined by the status signal. A 5 V signal is fed from the data handling subsystem to one of the status contacts. When the relay is set to the nominal mode, the contacts are closed and the 5 V is short circuited via a resistor located in the data handling subsystem and the status of the relay is noted. When the Back mode is entered, the status contacts become open and the 5 V is no longer short circuit. Again this change of status is noted by the data handling subsystem.

It should be noted that switching between LCL modes is forbidden whilst the coolers are active or the CDE is powered. Hence the CDE must be powered down when switching between Launch Lock mode (4 LCL) and nominal operating mode (2 LCL) or from nominal operating mode (2 LCL) to backup mode (4 LCL) .

9. MODES OF OPERATION

9.1 Standby Mode

Upon power up, all telecommand bits are reset to zero by internal power-on-reset circuitry and the CDE enters its Standby (low power) Mode and consumes approx. 5 watts. The bus input current will be in the range 0.14 to 0.18 Amps.

In this mode both Compressor PWM drive stages and both Displacer linear drive stages are disabled and the Compressor and Displacer motors are free to move. Also the control loops are not enabled. Hence the DC telemetry reading is non-specific, and the AC telemetry reads zero since effectively zero command has been sent.

9.2 Launch Lock Mode

To enter Launch Lock Mode, a telecommand must be sent to enable both Compressor and Displacer control and drive stages. Both the Compressor and Displacer amplitudes are set to zero in this mode. Hence the Launch Lock mode is identical to the nominal mode of operation but with the amplitude of the mechanisms set to zero. Since all amplitudes are set to zero, the drive telemetry (DC) will read 0 volts.

Since the mechanisms are held at zero amplitude, any movement of the motors due to external vibration, etc. will be minimised. The power required to prevent the pistons from hitting the end stops, will depend on the external vibration levels applied. However, when the external vibration is zero, the power consumption will be in the range 10 to 12 watts and the input current will be in the range 0.35 to 0.4 A.
Note: In Launch Lock mode both CDE's should be "Master".

9.2.1 Operational Mode

In Operational Mode, the CDE will drive the Compressor and Displacer motors to achieve the required cooling.

Telecommands are sent to take the CDE out of Launch Lock Mode and into Operational Mode.

Once in the operational mode, the Displacers will be set to a fixed amplitude (preset by on-board links) but appropriate bits must be set to successively increase the amplitude of the Compressor stroke.

The operational mode is split into two further modes. These are the Nominal mode and the Backup mode. In the Nominal mode four Compressors operate at 23 watts (5-6 mm) each and two CDEs operate in a Master/ Slave configuration, whilst in the Backup mode one CDE drives two compressors at 44 watts each (8-9mm).

In all the above modes it is assumed that the LCLs and relay have previously been configured for the appropriate mode as given in Section 11.5 on flight procedures.

9.3 Master / Slave Synchronisation

A CDE unit may be defined, by telecommand, to be either a Master or a Slave. At power up, both are initially Masters.

When defined as a Master, a CDE operates entirely from the internal crystal clock and generates two outputs; a CLK_OUT and SYNC_OUT signal. The CLK_OUT signal is the internal clock signal and the SYNC_OUT signal is a pulse which is one internal clock period wide, and occurs when the Master Compressor drive is at 90°.

When defined as a Slave, a CDE operates not from internal clocks, but from these Master CDE generated signals. Upon receipt of a SYNC_OUT signal from the Master, the Slave CDE Compressor drive is reset to 0°.

Thus, the cooler operating frequency of multiple CDEs may be synchronized to a single CDE. For integral, with 2 CDE units, this facility allows the ripple component of power taken from the spacecraft bus to be minimized.

When defined as a Slave; if the CLK_IN signal should be lost, then to prevent damage occurring to either the CDE, the drive coils or the pistons, the slave CDE will automatically reduce all demand signals to zero amplitude.

If the CLK_IN signal returns, then the demand signals will return to their previous operating conditions.

If the SYNC_IN signal is lost after power-up and entering Slave Mode, no effect will be noticed and the Master and Slave will continue to be synchronized at 90°.

If the SYNC_IN signal is lost before entering Slave Mode, then both CDE units will be synchronised, but to an undetermined phase.

Note: Accidental selection of two slaves would result in neither unit operating since there would be no clock present. Accidental selection of two masters would permit normal operation of the cooler system at low demand levels. However, as the power is increased, the summed current through the 4 LCLs could be outside the power specification sustainable by the INTEGRAL spacecraft.

10. TELECOMMANDS

The CDE is controlled by a single 16 bit serial telecommand which determines the various modes of operation of the cooler system and two high power telecommands for switching the power relay as described in the Power Interface Section (Section 7).

In the serial telecommand the most significant bit (MSB) is transmitted to the CDE first. This is designated Bit 0. The last bit is transmitted (LSB) is designated bit 15.

The Table below shows the designation of each bit within the 16 Bit serial telecommand word used in order to set up the CDE.

Table 2 16 Bit Telecommand Word

Telecommand		Compressor Function
B0	MSB	Master / Slave mode select. (0 = Master, 1 = Slave)
B1		Compressor 1 / Displacer 1 drive enable. (1 = enable)
B2		Compressor 1 amplitude 5 – MSB
B3		Compressor 1 amplitude 4
B4		Compressor 1 amplitude 3
B5		Compressor 1 amplitude 2
B6		Compressor 1 amplitude 1
B7		Compressor 1 amplitude 0 – LSB
B8		Displacer Mode (0 = Launch Lock. 1 = Nominal)
B9		Compressor 2 / Displacer 2 drive enable. (1 = enable)
B10		Compressor 2 amplitude 5 – MSB
B11		Compressor 2 amplitude 4
B12		Compressor 2 amplitude 3
B13		Compressor 2 amplitude 2
B14		Compressor 2 amplitude 1
B15	LSB	Compressor 2 amplitude 0 – LSB

Bit 0 defines the CDE as either a Master or a Slave. Upon power-up the CDE is a Master.

Bit 1 enables the power drives for Compressor 1 and Displacer 1. Upon power-up these mechanisms are disabled.

When enabled, Compressor 1 Control Loop is activated and the Compressor is in Launch Lock mode.

Bits 2 to 7 define the displacement amplitude for Compressor 1.

Bit 8 defines the operational mode for both Displacer 1 and 2.

Similarly, Bit 9 enables the power drives for Compressor 2 and Displacer 2.

Bits 10 to 15 define the displacement amplitude for Compressor 2.

11. COMMAND SEQUENCE

This section briefly describes the command sequence and gives a set of four flow charts, which will be the basis for the operating procedures for flight.

11.1 Operating sequence

The telecommand bits described in the last section must be set in a defined order otherwise damage to the system may occur.

It should be noted that when commanding the compressor amplitude, never start at high amplitude levels as damage to the compressor may result and never exceed the maximum telecommand allowed for the particular CDE/cooler pair.

Before powering up, select the relay position appropriate to the mode required (see Section 8.1). The main mode of operation will be the Nominal mode in which two compressors are powered from a single LCL. The command order for Power Up is as follows:

a. The first command selects the Master/Slave configuration. It is X,000000,00,000000 where X =0 for a Master and 1 for a Slave. There will be no indication of the selected mode on telemetry at this stage. In the Nominal mode one CDE will be set to be a master (Bit 0 = 0) while the other will be set to be a Slave (Bit 0 = 1).

b. The second command is X1,000000,01,000000 which enables the Compressors and Displacers. (Here the MSB is on the left and the LSB is on the right as per ESA convention - see remarks later). This is the Launch Lock case, since now the control loops have been enabled. Both the AC and DC telemetry will read 0V because we have zero command.

c. To switch the Displacers 'ON' select X1, 00000011,000000. The displacers will now be moving with an amplitude of 1.7 mm and the DC telemetry will give a reading proportional to this. There is no AC telemetry associated with the displacers.

d. Small motion of the compressor is produced by sending X1, 000XXX,11,000XXX where X is either a 0 or a 1. Note that with the 6 bits defining the amplitude of the compressor shown, the LSB is on the right and the MSB is on the left. By increasing the amplitude in a binary manner the desired amplitude can be obtained to give X1,XXXXXX,11,XXXXXX.

The command order for Power Down is the reverse of the Power Up order.

11.2 Power Up Sequence (Nominal and backup)

Not only is the command sequence important but on Power Up the dwell times between certain stroke lengths are also important and these are given below.

The amplitude for the nominal mode (25 watt) must be increased in a number of binary steps over a period of 4 hours when the final amplitude will be reached. After this time the drive telemetry and cryo temperature will be as per the calibration tables. The stroke, maximum step size, minimum delay between steps, and dwell times between certain amplitudes is given in the table below.

Table 3 Stroke Length Versus Dwell Time (Nominal Mode)

Stroke length in mm	Maximum step size in mm	Minimum delay between steps	Min. dwell times at the maximum stroke
0 to 3 mm	0.5 mm	1 second	2 minutes
3 to 5 mm	0.5 mm	1 second	5 minutes
5 mm to 7 mm	0.25 mm	1 second	0.5 hours

For the back up mode (44 watt), the amplitude must be increased in a further series of steps. A table giving the corresponding parameters to that given in the above table follows.

Table 4 Stroke Length Versus Dwell Time (Back Up Mode)

Stroke length in mm	Maximum step size in mm	Minimum delay between steps	Min. dwell times at the maximum stroke
0 to 3 mm	0.5 mm	1 second	2 minutes
3 to 5 mm	0.5 mm	1 second	5 minutes
5 to 7 mm	0.5 mm	1 second	0.5 hours
7 to 8 mm	0.5 mm	1 second	0.5 hours
8 to 8.5 mm	0.5 mm	1 second	1.0 hours
8.5 mm to max stroke	0.25 mm	1 second	2.0 hours

It is appreciated that this sequence has taken a considerable time for the final amplitude to be reached. The calibration tables give the margins in hand and it is possible to reach higher strokes quicker (and hence a cold temperature reached sooner). However there is a thermal stabilisation process to consider so that even if the appropriate strokes are reached sooner, the cold temperature will still take some time to stabilise.

The actual upper binary value for safe operation will be given at a later date after the performance tests have been completed. Once these results are known it may be possible to adjust the above procedure for optimum results.

It should be noted that once the piston is moving with a reasonable amplitude (say +/- 2.5 mm) the phase relationship between the two CDE's can be deduced from observation of the AC telemetry of each CDE.

11.3 Power Down Sequence

The power down sequence is the reverse of the power up sequence except that the whole sequence can be completed more quickly since dwell times are not necessary.

Never go from a maximum stroke situation to zero stroke in one telecommand

11.4 Eclipse Case

When going into eclipse it is likely that the overall power to the cooler system will have to be reduced and when coming out of eclipse restore the power to its nominal value. The exact telecommand to accomplish this is given in the calibration and performance tables below. This change in power from the Nominal mode of operation to the reduced stroke case and back again, can be performed with reference to the sequence given in the tables of 11.2.

It should be appreciated that when coming out of eclipse and normal operation is resumed, the cryo temperatures will take some time to stabilise.

11.5 Flight Procedures

The following section provides a set of flow charts in order to cater for the four flight procedures identified. These four cases are, a) power on for launch, b) power on for nominal mode operation using one LCL, c) a set amplitude procedure and d) a power down procedure.

It is assumed normal operating temperature for the CDE has been reached and that the temperature of all mechanisms (as measured on the PRT T/M) is within the range –20 to +50 deg C required.

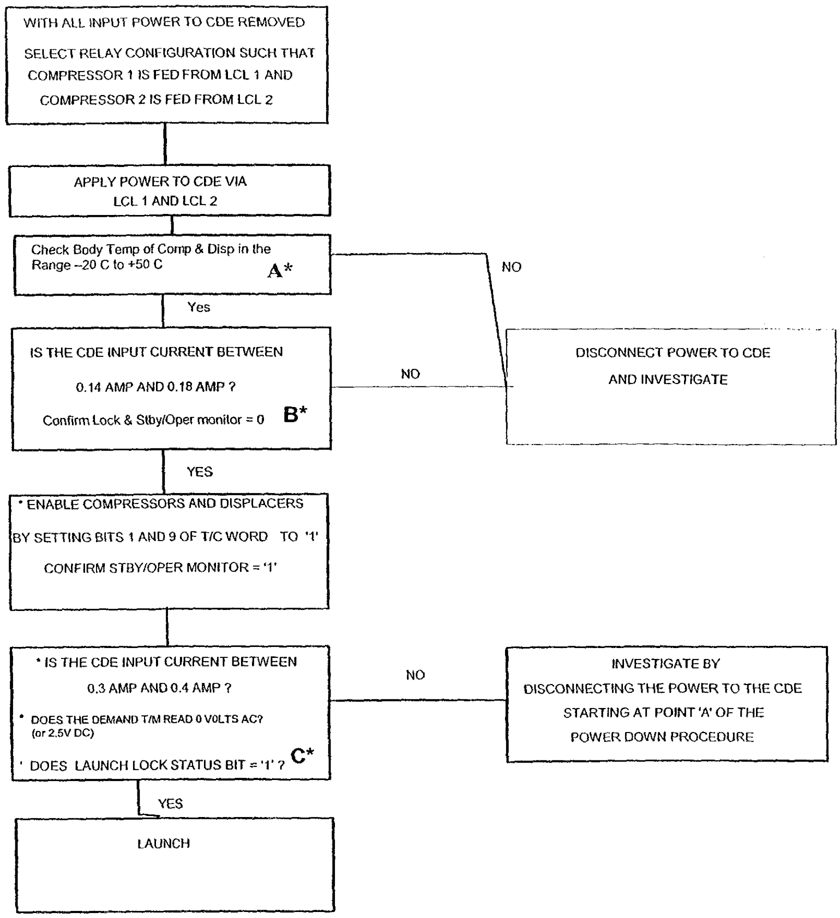


Figure 4 Flow Chart for Power-Up Sequence in Launch Lock

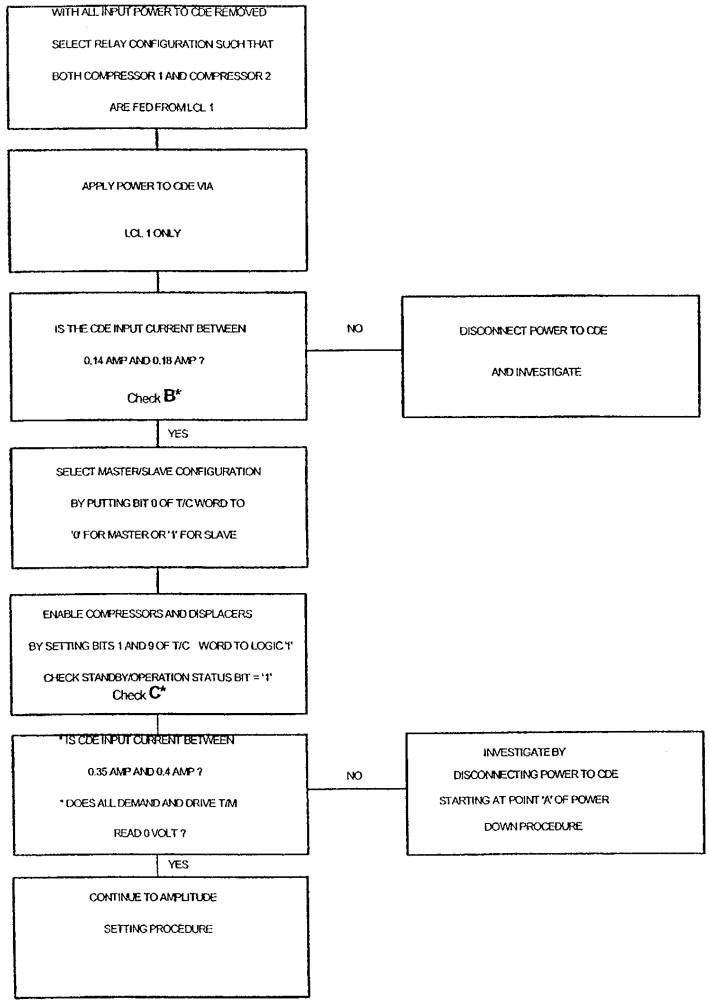


Figure 5 Power Up Sequence for Nominal Mode

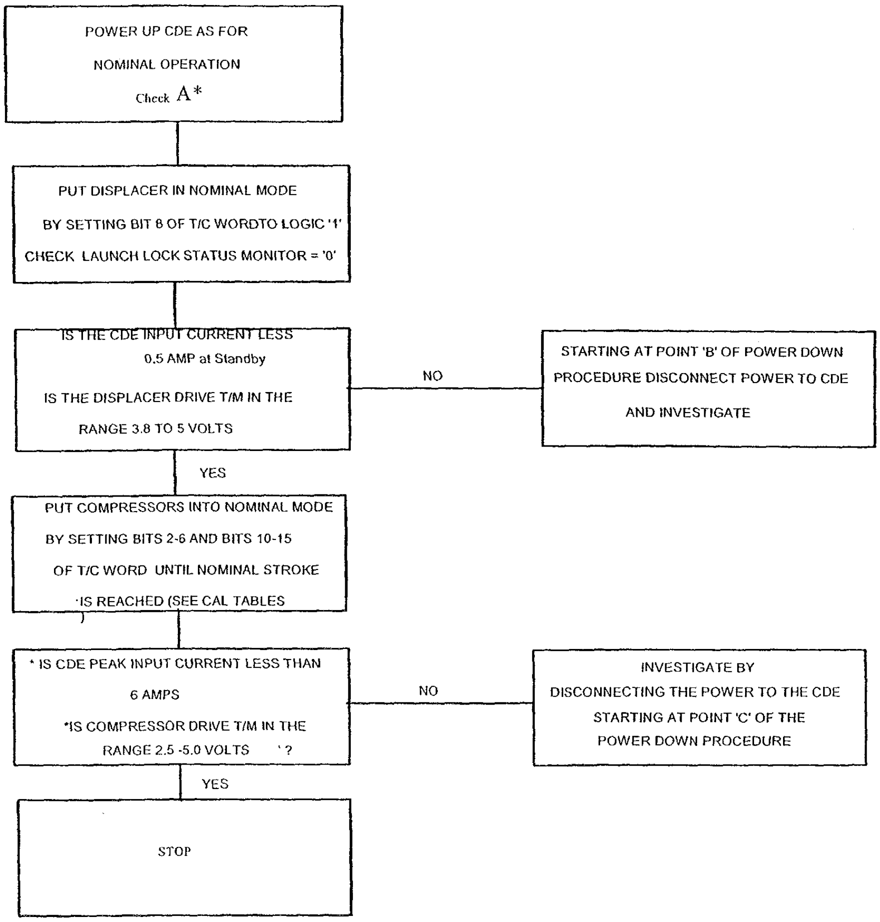


Figure 6 Amplitude Setting Procedure for Nominal Mode

Note : The above chart is to configure one CDE in the nominal operational mode.
When both CDEs have been configured in this mode, the last step of the procedure is to check the phase between the CDE demand signals.

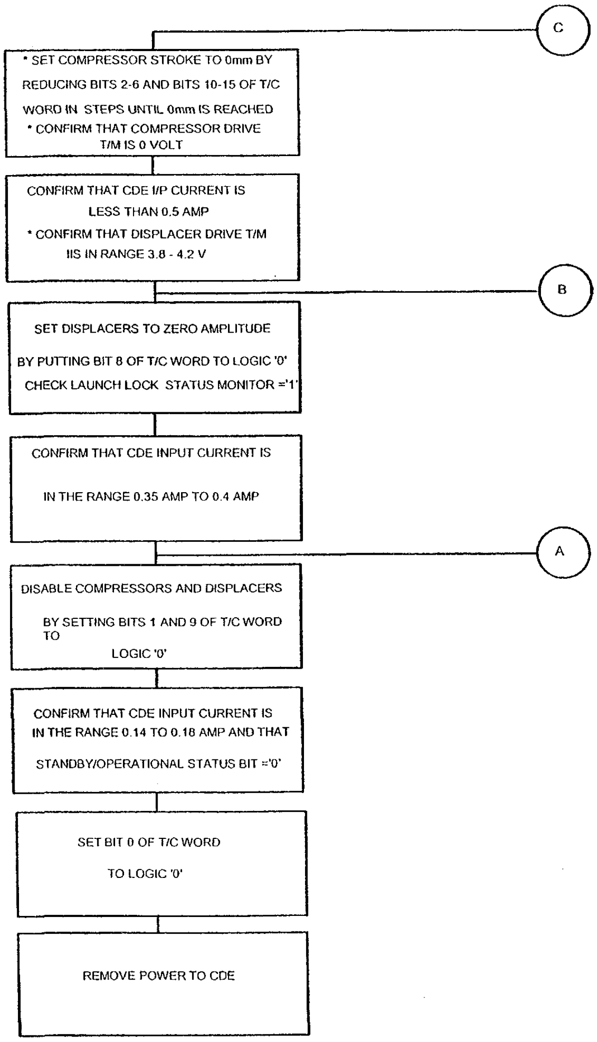


Figure 7 Flow Chart for Powering Down

11.6 Calibration Tables

The table on the next page, defines the Telecommands and expected telemetry associated with a particular Compressor displacement amplitude.

It should be noted that when commanding the compressor amplitude, never start at high amplitude levels as damage to the compressor may result or the LCL's may trip out.

Never exceed the maximum telecommand allowed.

Note: The CDE is provided with a limiting circuit such that if a telecommand is sent which is higher than that allowed the amplitude of the sinewave generated by the CDE will be limited.

THE TABLE IMMEDIATELY BELOW APPLIES TO THE EM CDE DRIVING COMPRESSORS 'C' AND 'D'. THIS TABLE WILL BE UPDATED TO SHOW THE CORRESPONDING DRIVE AND DEMAND T/M, TELECOMMANDS, STROKE AND POWER FOR ALL FM COMPRESSORS USING THE FS AND FM CDE's.

Note: Only the amplitudes for 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 mm and relevant intermediate operating strokes (eg strokes for 23 and 44 watt) will be provided.

Table 5 Typical Compressor T/C Amplitudes Using FM Coolers C and D+EM CDE

(Bristol March 1999)

Amp5	Amp4	Amp3	Amp2	Amp1	Amp0	No.	Compressor "C" Amp mm p2p	Compressor "C" Power (Watt)	Compressor "D" Amp mm p2p	Compressor "D" Power (Watt)	Drive T/M
0	1	0	0	0	1	17	3.15	3.25	2.7	2.9	
1	0	0	0	0	1	33	6.0	13.75	5.1	11.8	
1	0	0	0	1	0	34	6.15	14.65	5.25	12.2	
1	0	0	0	1	1	35	6.23	15.5	5.4	13.0	
1	0	0	1	0	0	36	6.45	16.5	5.55	14.0	
1	0	0	1	0	1	37	6.75	17.75	5.7	14.5	
1	0	0	1	1	0	38	6.9	18.75	5.85	15.5	
1	0	0	1	1	1	39	7.05	19.9	6.0	16.0	
1	0	1	0	0	0	40	7.2	21.0	6.15	17.0	
1	0	1	0	0	1	41	7.35	22.1	6.3	18.0	
1	0	1	0	1	0	42	7.5	23.5	6.45	19.0	
1	0	1	0	1	1	43	7.58	24.75	6.6	20.0	
1	0	1	1	0	0	44	7.65	26.0	6.75	21.0	
1	0	1	1	0	1	45	7.8	27.75	6.9	21.8	
1	0	1	1	1	0	46	7.95	29.0	7.05	23.0	
1	0	1	1	1	1	47	8.1	30.75	7.2	24.0	
1	1	0	0	0	0	48	8.25	32.25	7.35	25.0	
1	1	0	0	0	1	49	8.4	33.75	7.5	26.1	
1	1	0	0	1	0	50	8.55	35.5	7.5	27.5	
1	1	0	0	1	1	51	8.7	37.25	7.86	28.5	
1	1	0	1	0	0	52	8.93	39.0	7.92	30.5	
1	1	0	1	0	1	53	9.0	41.0	8.1	31.5	
1	1	0	1	1	0	54	9.08	43.0	8.1	32.25	
1	1	0	1	1	1	55	9.15	44.75	8.25	37.25	
1	1	1	0	0	0	56			8.25	37.25	
1	1	1	0	0	1	57			8.28	39.75	
1	1	1	0	1	0	58			8.33	40.0	
1	1	1	0	1	1	59			8.4	40.6	
1	1	1	1	0	0	60			8.625	42.0	
1	1	1	1	0	1	61			8.7	43.2	
1	1	1	1	1	0	62			8.775	45.0	
1	1	1	1	1	1	63					

Table 6 Typical Compressor T/C Amplitudes Using FS Coolers C and D +EM CDE

Amp5	Amp4	Amp3	Amp2	Amp1	Amp0	No.	Compressor "C"		Compressor "D"		Comp C	CompD	Temp @ 2W (K)
							Amp mm p2p	Power (Watt)	Amp mm p2p	Power (Watt)	Drive T/M	Drive T/M	
0	1	0	0	1	0	18							
0	1	0	0	1	1	19							
0	1	0	1	0	0	20	3.0	3.81	3.0	3.33			272.0
1	0	0	0	0	1	33							
1	0	0	0	1	0	34							
1	0	0	0	1	1	35	5.0	12.97	5.0	11.98			188.9
1	0	0	1	0	0	36							
1	0	1	1	1	1	47							
1	1	0	0	0	0	48	7.0	27.6					137.4
1	1	0	0	0	1	49			7.0	25.5			
1	1	0	0	1	0	50							
1	1	1	1	0	0	60							
1	1	1	1	0	1	61	9.0	49.88					
1	1	1	1	1	0	62							113.5
1	1	1	1	1	1	63			9.00	47.05			

Table 7 : Typical Compressor TC Amplitudes Using FS Coolers C and D +FS CDE

Amp5	Amp4	Amp3	Amp2	Amp1	Amp0	No.	Compressor "C" Amp mm p2p	Compressor "C" Power (Watt)	Compressor "D" Amp mm p2p	Compressor "D" Power (Watt)	Comp C T/M (V)	Comp D T/M (V)	Temp (K)@2W Load
0	1	0	1	0	0	20	3.0	3.82	3.0	3.65	1.498	1.351	269.25
0	1	0	1	0	1	21							
1	0	0	1	1	1	39							
1	0	1	0	0	0	40	6.0	18.01	6.0	16.7	2.79	2.586	158.5
1	0	1	0	0	1	41							
1	0	1	1	1	0	46							
1	0	1	1	1	1	47	7.0	24.4	7.0	24.5	3.286	3.05	135.7
1	1	0	0	0	0	48							
1	1	1	0	1	0	58							
1	1	1	0	1	1	59			8.7	43.5		4.11	112.25
1	1	1	1	0	0	60	8.7	48.2			4.5		
1	1	1	1	0	1	61	9.0	49.9	9.0	46.9	4.69	4.294	110.05

Table 8 Typical Compressor TC Amplitudes Using FM Coolers A and B + FM1 CDE

Amp5	Amp4	Amp3	Amp2	Amp1	Amp0	No.	Compressor "A"		Compressor "B"		Comp A T/M (V)	Comp B T/M (V)	Temp (K) @ 2W Load
							Amp mm p2p	Power (Watt)	Amp mm p2p	Power (Watt)			
0	1	0	1	0	0	20							
0	1	0	1	0	1	21							
1	0	0	1	1	1	39							
1	0	1	0	0	0	40							
1	0	1	0	0	1	41	6.0	16.4	6.0	17.4	2.50	2.53	144.4
1	0	1	1	1	0	46							
1	0	1	1	1	1	47							
1	1	0	0	0	0	48	7.0	24.7	7.0	26.0	2.99	3.09	122.2
1	1	1	0	1	0	58							
1	1	1	0	1	1	59							
1	1	1	1	0	0	60			8.53	47.0	4.224	4.253	98.7
1	1	1	1	0	1	61	8.74	47.1					

Table 9 Typical Compressor TC amplitudes using FM Coolers C and D + FM2 CDE

Amp5	Amp4	Amp3	Amp2	Amp1	Amp0	No.	Compressor "C" Amp mm p2p	Compressor "C" Power (Watt)	Compressor "D" Amp mm p2p	Compressor "D" Power (Watt)	Comp C T/M (V)	Comp D T/M (V)	Temp (K)@2W Load
0	1	0	1	0	0	20							
0	1	0	1	0	1	21							
1	0	0	1	1	1	39							
1	0	1	0	0	0	40	6.0	15.2	6.0	16.5	2.432	2.162	152.2
1	0	1	0	0	1	41							
1	0	1	1	1	0	46							
1	0	1	1	1	1	47	7.0	23.2	7.0	24.6	2.96	2.602	129.9
1	1	0	0	0	0	48							
1	1	1	0	1	0	58							
1	1	1	0	1	1	59							
1	1	1	1	0	0	60							
1	1	1	1	0	1	61	8.91	47.2	8.53	46.5	4.392	3.686	103.7

12. TELEMETRY

12.1 General

The Cooler system provides the means to monitor 10 analogue telemetry channels and two digital channels within each CDE. These have been conditioned to allow direct interfacing to the data handling subsystem. The 10 analogue telemetry channels are made up as follows:

Four temperature monitors providing DC outputs as follows:

- Temperature 1, (J4/5)
- Temperature 2, (J4/6)
- Temperature 3, (J4/12)
- Temperature 4, (J4/13)

Two Compressor drive amplifier drive monitors providing DC outputs, designated:

- Compressor 1 drive amplifier, (J4/2)
- Compressor 2 drive amplifier, (J4/3)

Two Displacer drive amplifier drive monitors providing DC outputs, designated:

- Displacer 1 drive amplifier, (J4/9)
- Displacer 2 drive amplifier, (J4/10)

Two Compressor Demand monitors providing sinusoidal outputs, designated as:

- Compressor 1 demand (J4/8)
- Compressor 2 demand (J4/15)

All analog telemetry channels are single-ended and are referenced to the internal analog 0 V, (J4/4 and J4/11).

The two digital telemetry channels comprise the following:

- Launch Lock status monitor (J1/8) (Launch Lock = '1')
- Standby/Operational status monitor. (J1/7) (operational = '1')

The modes relating to these bits are given in the table below

Launch Lock Status Monitor	Stby /Oper Monitor	
0	0	Standby Mode
0	1	Normal Mode
1	1	Launch Lock Mode
1	0	Not Applicable

Means to monitor the relay status within each CDE is also provided by passing the status of the relay contacts back to the Data Handling Subsystem.

12.2 Drive Telemetry

Although monitoring points are available for ground testing, the main inflight monitoring available as regards to the operation of the Cooler system, consists of DC telemetry (0 - 5 Volts), AC telemetry (0 - 5 Volts), the digital telemetry and the Temperature monitors mentioned above.

The DC telemetry is the telemetry associated with the amplitude of the drive signal. It is derived from a peak detector circuit which processes the signal at the output of the control circuits after the signal has been compensated. This signal is available once the control loops are enabled and therefore is available in both the launch lock and nominal operating modes. However since there is zero demand at Launch Lock, the reading will be 0 Volts until the vibration at Launch (simulated or real) occurs. During vibration, the output will be random but the voltage profile will have its peak value at maximum vibration.

A block diagram showing the demand and drive TM outputs is shown below:

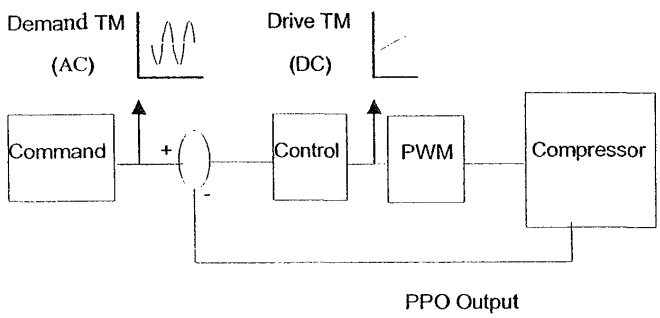


Figure 8 Drive and Demand Telemetry

Note: The above peak detector circuit does not detect individual peaks but detects peaks of the 44Hz repetitive sinewave by charging up a circuit over a few cycles (5-10) thus after a very short time the peak is detected.

12.3 Demand Telemetry

The AC telemetry is the telemetry associated with the Compressor Demand signal and is the 43.42Hz sinewave that feeds into the Compressor Control circuits. It is an offset sinusoidal representation of the digital commands sent to the Compressors and is mainly used for deducing the phase relationship between the two CDE's when operating in Master/Slave mode. However it can be used to a check that the correct Compressor amplitude has been telecommanded and for fault finding purposes (see later).

There is no monitor to verify whether the CDEs are in the Master or Slave configuration. At power up, both CDEs will be in the Master configuration and only when Bit 0 is set high will the Slave configuration be selected.

However if one CDE is set for the Master configuration and the other is set for Slave, the demanded sinewaves from the AC telemetry (see above) will provide the information such that the 90 degree phase relationship between the two CDEs can be deduced from ground. If both CDEs were selected to be Masters, the sinewaves from each CDE could have any phase relationship and consequently the input current peaks would not be minimised.

12.4 Temperature Monitoring

The four temperature monitoring channels comprise temperature conditioning circuits within the CDE and are intended to be used for monitoring the temperature of the bodies of the two compressors and two displacers in the –30 deg C to +50 deg C temperature range.

13. USING THE MONITORS

13.1 General

The monitoring of the compressor and displacer drive voltage give an indication of the amplitude of their pistons; changes in telecommanded amplitude as small as 0.05 mm can be observed on the ground. This amplitude can also be deduced from monitoring of the compressor demand voltages although their prime purpose is for deducing the phase relationship between CDEs. The actual amplitude of the pistons can only be known accurately by using the calibration tables; a sample of which is shown in the Section 11.6.

13.2 Phase Relationship between each CDE

In the Master/Slave mode of operation, there is a 90 degree phase shift between the telemetered 43.42 Hz compressor signals of the Master and the Slave. There is no direct measurement of this relationship within the Cooler system. However if the two signals are sampled near simultaneously (within 100 microseconds say) then the instantaneous amplitude of both signals is known enabling the phase relationship to be deduced as follows.

The signals are sampled once every 8 seconds (RD 5 Ch. 4.5.1.2.) which is below the Nyquist rate. Hence, because the sampling signal and the 43.42 Hz sinewaves are asynchronous to each other, the sinewaves will be sampled at slightly different places on the waveform (but at different times). This fact will allow the phase relationship between the signals from the two CDEs to be deduced.

13.3 Typical results

Both the Compressor and Displacer are controlled by position loops which generate the power amplifier drive signals.

Compressor and Displacer drive amplifier telemetry signals are provided which indicate the magnitude of the drive signal sent to the relevant power amplifier. The Telemetry range is 0 to 5 V.

Typically, for four FM/FS 50/80 K compressors operating at 25 W, and a cold finger heat load of 2000 mW, the telemetry signals are expected to have the following readings:

Displacer drive amplifier	3.8V +/- 0.3 V
Compressor drive amplifier	3.0V +/- 0.3 V

Note: The T/M readings given in Section 16, Table 12 are for the EM only. FM/FS Circuitry for TP 125 and TP 126 has been modified in order to bring them into the 0-5 V range.

Table 10 Compressor and Displacer Drive Telemetry

Monitoring of these signals will indicate, for example, if a compressor is stiffening.

If this occurs, the position control loop will increase the power amplifier drive to maintain the same Compressor and/or Displacer amplitude (and thus cooling effect), and the relevant telemetry signal will therefore increase in value. Drive TM will also increase while cooling occurs (gas stiffness effect)

A typical 50/80 K Compressor telemetry plot is shown in Figure 9 below, where the drive telemetry voltage is plotted against the piston stroke in mm. Actual curves taken during performance testing of the flight models is given in Section 16.
Tests have shown that the variation in the t/m given by the CDE over the temperature range –20 to +50 is no greater than 50mV.

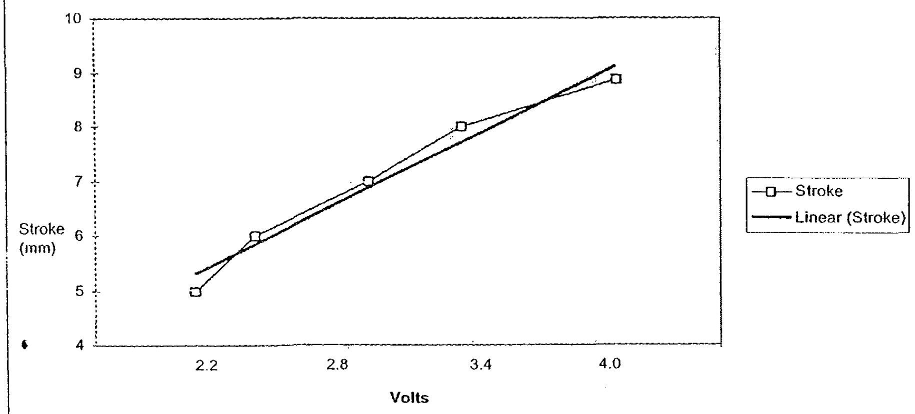


Figure 9 Typical Compressor Telemetry Plot

Discussion:
The tolerance on the above "typical" graph depends very much on the Coolers. This graph serves as a first guide only, now that true operating data is available this should be used. This is why in section 16 stroke vs TM volts plots for each Cooler with its CDE combination are included. (Plots 5, 7, 9, 12,15). For example for FM take plots 12 and 15. These show at 6mm strokeCooler A gives 2.56V, B 2.64; then C 2.53 and D 2.25. Roughly 2.4V +/- 10%.
At 9mm stroke A 4.4, B 4.43, C 4.75, D 3.84; roughly 4.1V +/- 10%.
It is suggested that a tolerance of +/- 10% is assumed as a guide for normal operation at 2W load. However the tolerance needs to be re-examined when considering the actual operating load and the stroke conditions.

13.4 Using the Temperature Monitors

The temperature of the mechanism bodies is telemetered referenced to ground after conditioning by the four temperature processing circuits. Observation of these temperatures can help in fault finding, and could for example, indicate the onset of a piston tightening.

14. TEMPERATURE SENSOR CONDITIONING

The four temperature sensor conditioning circuits provided within the CDE can interface with any suitable temperature sensor but will require calibrating for the particular sensor used. These circuits interface with the temperature sensors which are mounted on the body of the mechanisms. The temperature sensor conditioning circuit provided is shown in Figure 10.

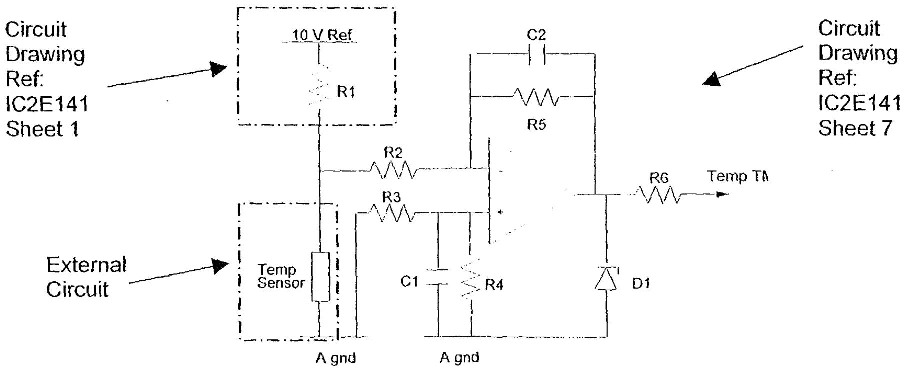


Figure 10 Temperature conditioning circuit within the CDE

The table below gives the characteristics for the PRT sensor model 118MM.

Table 11 100Ω PRT Element Characteristics (Model 118MM)

Temperature		Resistance	Temperature		Resistance	Temperature		Resistance
K	°C	RTHERM (Ω)	K	°C	RTHERM (Ω)	K	°C	RTHERM (Ω)
73	*-200*	17.22	173	*-100*	59.69	273	*0*	100.00
93	*-180*	25.90	193	*-80*	67.89	293	*20*	107.87
113	*-160*	34.54	213	*-60*	76.01	313	*40*	115.69
133	*-140*	43.04	233	*-40*	84.07	333	*60*	123.47
153	*-120*	51.42	253	*-20*	92.06	353	*80*	131.21

In the temperature range –30 deg C to + 50 deg C, the BOL total uncertainty is +/- 1.7 K/ deg C, the EOL total uncertainty is +/- 3.7 K/deg C. Quantisation errors are strictly dependent on the data handling system and not the CDE. However if 8 bit accuracy is assumed the total error due to quantisation is +/- 0.658 K/deg C.

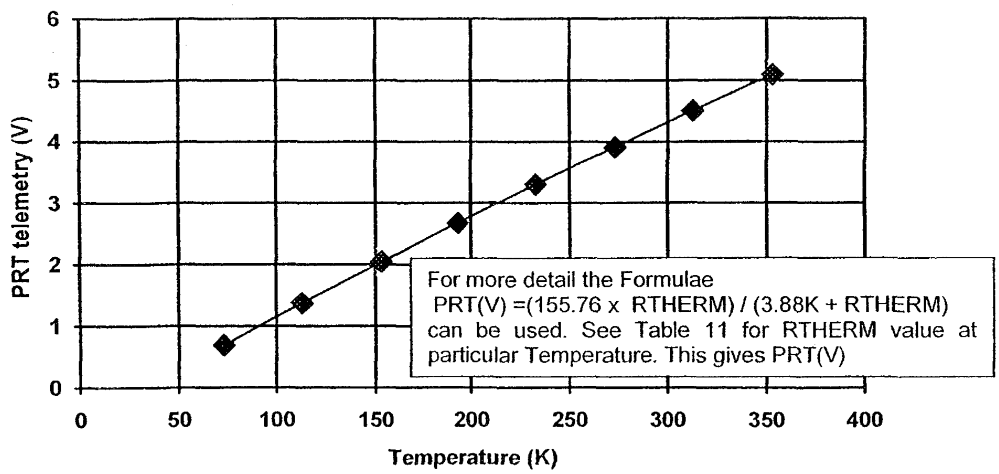


Figure 11 Calibration Curve for PRT Conditioning

15. OPTIMUM OPERATION OF THE COOLER SYSTEM

The system must be operated such that the detector cooling requirements are met, but without the peak current tripping the LCL or excessive micro-vibration taking place. This implies that pairs of compressors must have equal amplitudes (but not necessarily equal telecommands); the amplitude being consistent with the desired cryo temperature. In this way current peaks on the bus will be equal and if the CDEs are set in the Master/Slave configuration overall mean and peak current taken from the bus will be minimised. Equal stroke lengths ensure vibration cancellation (minimum vibration).

To achieve this situation the telecommands given in the performance tables below must be adhered to rigorously. The table represents the calibration of the system for various compressor stroke lengths using a defined test set up. The tables given below give the performance achieved for the EM CDE and Compressors 'C' and 'D'. For the FM CDE/Compressors, a similar table will be produced.

16. PERFORMANCE TABLES & PLOTS

These tables present the performance data of the cooler system when it is operated with an INTEGRAL Test set in conjunction with a standard set of interface cables. To obtain the relevant power, wattmeters were placed in the input and output lines as close to the associated CDE as possible; the leads between wattmeter and CDE having their resistance minimised by using parallel wire connections. This standard Test configuration allows a performance comparison to be made when the Cooler System is operating in different situations. The results obtained are given in the tables below. In addition curves have been plotted from the data which gives the telecommand versus stroke, temperature versus stroke, and telemetry versus stroke. These are taken at a heatlift of 2 watts for the EM,FS and FMs. For the FMs this data is given for a 1.8 watt heat lift as well

Table 12 Performance Table for EM CDE operating with FS Coolers C and D

Cryogenic Cooler Characterisation Tests — Page .... of ....

Date:- | Cooler Model:- | CDE Model:- | I/P Bus Voltage:-

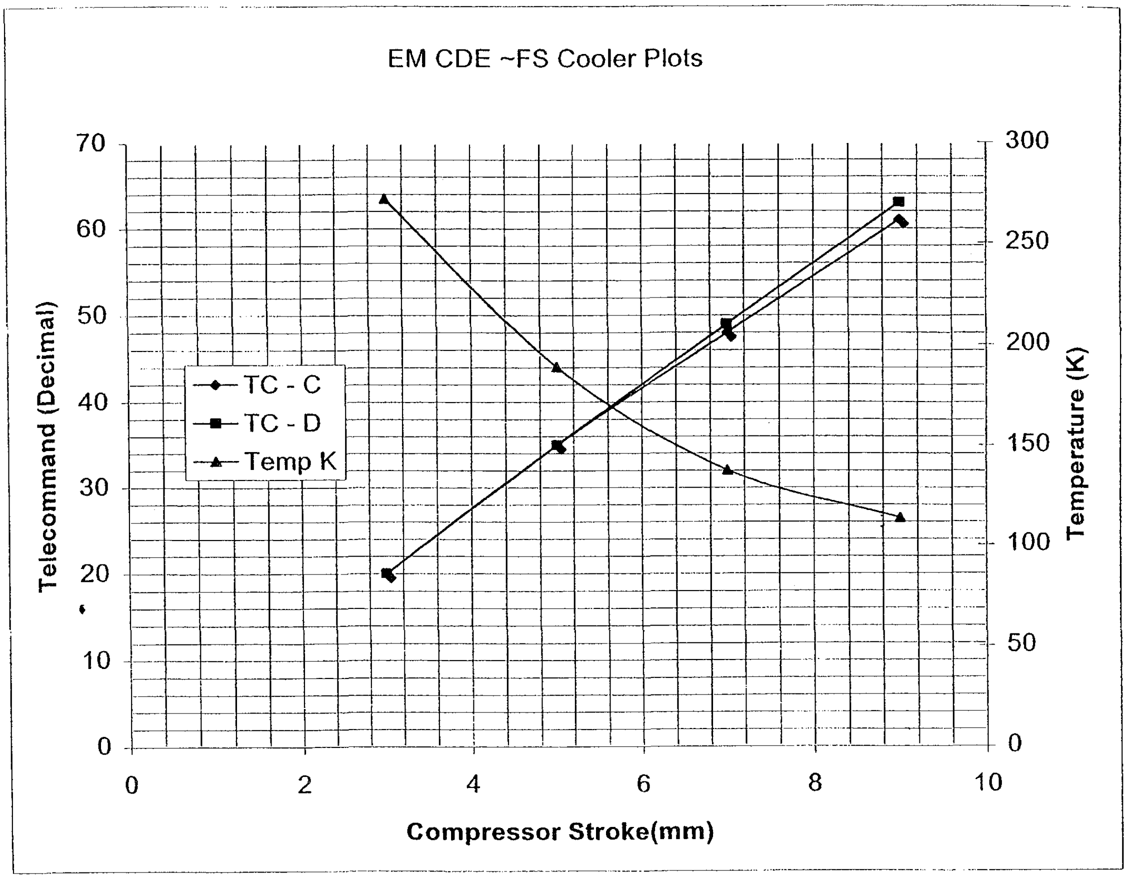
Test Engineer:- | Cooler Ser No:- | CDE Ser No:- | Ambient Temp (oC):-

Comments:-

Uncorrected Cold Tip Temp (°K)			PPO Displacements (mm)				TM Voltages (V)						Powers (W)				I/P Bus		Load Power	"C" Coolr Temp	"D" Coolr Temp
T/C CompC (dec)	T/C CompD (dec)	Ave Cold tip Temp	Com "C"	Com "D"	Disp "C"	Disp "D"	Com "C" (Volt) TP 123	Com "D" (Volt) TP 124	Dmd Peak "C" (Volt)	Dmd Peak "D" (Volt)	Disp "C" (Volt) TP 125	Disp "D" (Volt) TP 126	Com "C"	Com "D"	Disp "C"	Disp "D"	(W) *	(A)	(W)	(°C)	(°C)
63	63	108.2	8.55	8.73	3.41	3.41	3.39	2.64	3.8	3.6	5.65	5.68	39	45	1.0	1.2	122.5 (115)	4.37	2	28.8	29.7
55	55	117.4	7.98	8.01	3.35	3.42	2.99	2.44	3.44	3.48	5.52	5.66	30	35.5	0.725	0.925	99.3 (92)	3.52	2	26.8	27.8
48	48	132.3	6.99	6.99	3.28	3.3	2.59	2.15	3.06	3.06	5.37	5.51	22.2	26.0	0.55	0.7	76.45 (71)	2.74	2	25.2	26.2
39	38	158.6	5.97	5.97	3.24	3.24	2.13	1.88	2.56	2.56	5.14	5.36	13.95	16.0	0.363	0.463	54.64 (50)	1.93	2	22.6	23.2
34	31	188.4	5.25	5.19	3.27	3.27	1.89	1.71	2.15	2.22	5.02	5.28	9.0	11.0	0.275	0.375	43.04 (37.5)	1.47	2	21.7	22.3

*The power readings given in brackets are those taken from the wattmeter. The non-bracketed readings are calculated from i/p volts x i/p amps.

Plot1 (EM CDE ~ FS Coolers)
Compressor Stroke C , D is plotted against TC-C , TC-D and Cold Finger Temperature



Plot2 (EM CDE ~ FS Coolers)

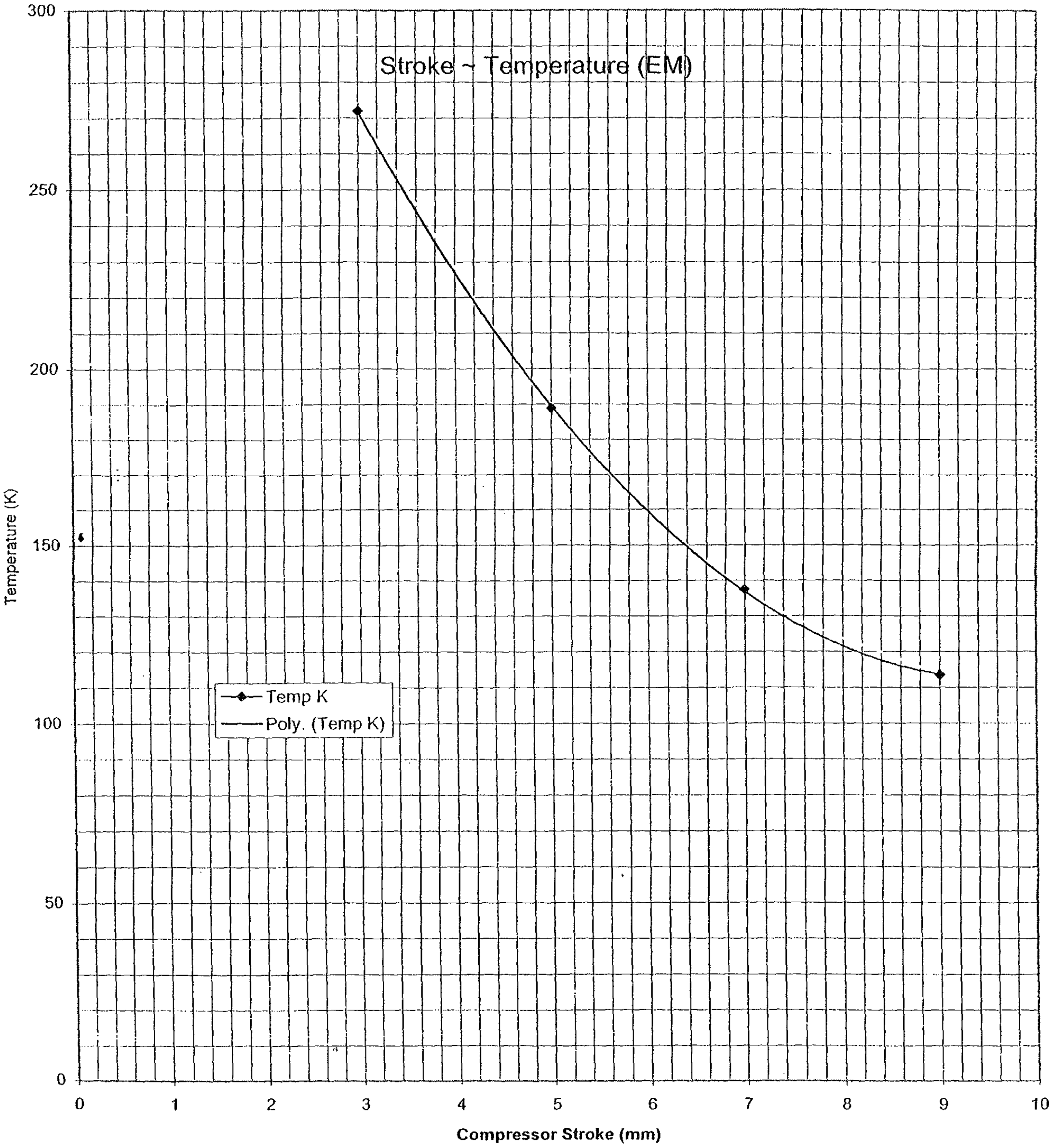


Table 13 - Characterisation Tests for 2W Load with CDE at 68° Phase Angle

FS CDE [S/N 0287982] , FS Coolers [BR10425]

Date/Time	Compressor C						Compressor D						Total CDE Input Power [W]	Avg H-BarTemp [K] @ 2W Load	Base Temp TR1 [°C]	Total CDE Current Waveform+RMS
	TC	PPO [V_{p-p}]	PWR [W]	Telemetry: Comp Amp Vdc	Telemetry: *Displ Amp Vdc	Telemetry: Comp Demand [V_{p-p}]	TC	PPO Vp-p	PWR Watts	Telemetry: Comp Ampli-Vdc	Telemetry: *Displ Amp Vdc	Telemetry: Comp Demand DC=2.45				
SPICO Vacuum Level 1.5·10^{-6} mbar, Dummy Displacer Vacuum Level < 10^{-4} mbar																
27-Jul-00 11:30	010100	2.80V (3mm$_{p-p}$)	3.82	1.498	4.96 *(3.62)	1.36	010100	2.80V (3mm$_{p-p}$)	3.65	1.351	5.073	1.36Vp-p	25.16	269.25	22.3	Tek00040 Tek00041 0.98A
28-Jul-00 10:50	101000	5.60V (6mm$_{p-p}$)	18.01	2.790	5.13 *(3.75)	2.68	101000	5.60V (6mm$_{p-p}$)	16.7	2.586	4.88	2.68	60.23	158.5	20.8	Tek00042 Tek00043 2.32A
29-Jul-00 7:15	101111	6.53V (7mm$_{p-p}$)	24.4	3.286	5.350 *(3.904)	3.08	101111	6.53V (7mm$_{p-p}$)	24.5	3.05	5.00	3.08	79.63	135.7	20.3	Tek00045 Tek00044 3.1A
10:30	111100	8.12V (8.7mm$_{p-p}$)	48.2	4.500	5.736 *(5.01)	3.90	111011	8.12V (8.7mm$_{p-p}$)	43.5	4.111	5.234	3.9	130.5	112.25	21.5	Tek00060 Tek00061 5.1A
12:00	111101	8.4V (9.0mm$_{p-p}$)	49.9	4.690	5.850 *(5.10)	4.00	111101	8.4V (9.0 mm$_{p-p}$)	46.9	4.294	5.442	4.00	137.2	110.05	20.8	Tek00048 Tek00049 5.3A
***Displacer telemetry re-scaled and displacer amplitude adjusted to reach 3.4 mm$_{p-p}$, SPICO Vacuum Level 1.8·10^{-6} mbar, Dummy Displacers Evacuated**																
30-Aug-00	101111	6.53V (7mm$_{p-p}$)	26.8	3.348	3.904	Not available	101111	6.53V (7mm$_{p-p}$)	25.1	3.118	3.576	A Tek00000 Comp PPOB Tek00000	81.1	128.6	Not available	Btek00001 1A/div/3.1A

Note: With modified CDE & Cooler set-up there is a ratio of PPO(mm) / PPO(Vp-p) = 1.0714. Thus 3mm(p-p) = 2.8Vp-p etc.

** Estimated values for equivalent amplitudes, following rework to rescale PPO output*

Table14 cont- Performance Tests with CDE at 68° Phase Angle

FS CDE [S/N 0287982] , FS Coolers [BR10425]

Date/ Time	Compressor C						Compressor D						Total CDE Input Power	Avg H-BarTemp [K]	Base Temp TR1 [°C]	Total CDE Current Waveform +RMS
	TC	PPO Vp-p	PWR Watts @ Load (mW)	Telemetry Comp Ampli-	Telemetry *Displ Amp	Comp Demand DC=2.46	TC	PPO Vpp	PWR Watts @ Load (mW)	Telemetry Comp Ampli-	Telemetry *Displ Amp	Comp Demand DC=2.46				
SPICO Vacuum Level 1.5·10⁻⁶ mbar, Dummy Displacer Vacuum Level < 10⁻⁴ mbar)																
30-Jul-00	111010	7.9V (8.46mm p-p)	44W @2000 mW	4.302	5.66 *(4.94)	3.78	111011	8.14V (8.72mm p-p)	44W@ 2000 mW	4.132	5.274 *(4.085)	3.88	126.64	114.5	23.1	Tek00062 Tek00063 4.9A
	111100	8.12V (8.7mm p-p)	48.4 @1800mW	4.515	5.75 *(5.02)	3.92	111011	8.12V (8.7mm p-p)	44.1 @1800mW	4.11	5.317 *(4.11)	3.92	130.8	108.5	Not available	Tek00058 Tek00059 5.1A
	111100	8.12V (8.7mm p-p)	49.0 @1600 mW	4.545	5.77 *(5.03)	3.92	111011	8.12V (8.7mm p-p)	44.3 @1600 mW	4.122	5.35 *(4.14)	3.92	132.32	104.0	Not available	Tek00056 Tek00057 5.1A
	111100	8.12V (8.7mm p-p)	48.8 @1400mW	4.592	5.81 *(5.07)	3.92	111011	8.12V (8.7mm p-p)	44.8 @1400mW	4.162	5.39 *(4.175)	3.92	133.3	100.2	Not available	Tek00054 Tek00055 5.2A
	110110	7.47V (8.0mm p-p)	39.5 @1600mW	4.015	5.615 *(4.90)	3.6	110110	7.47V (8.0mm p-p)	35.5 @1600mW	3.66	5.26 *(4.075)	3.6	109.73	111.2	Not available	Tek00052 Tek00053 4.3A
	110011	7.0V (7.5mm p-p)	33.2 @1600mW	3.632	5.524 *(4.825)	3.28	110010	7.0V (7.5mm p-p)	29.3 @1600mW	3.326	5.14 *(3.98)	3.28	92.3	117.4	Not available	Tek00050 Tek00051 3.6A

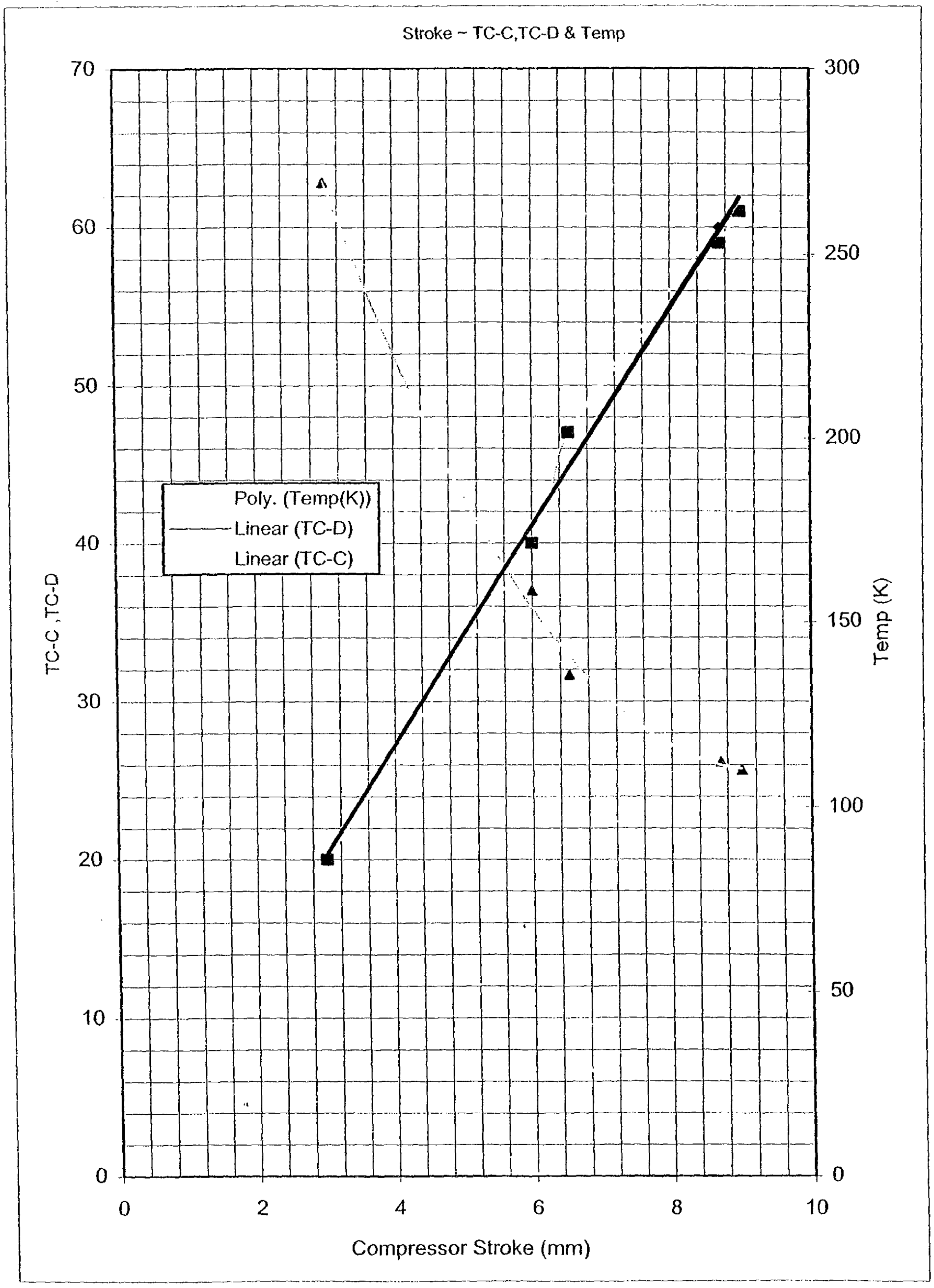
Displacer telemetry rescaled to 2/3 the voltage shown here and displacer amplitude adjusted to reach 3.4 mm_{p-p}, SPICO Vacuum Level $1.8\cdot10^{-6}$ mbar, Dummy Displacers evacuated

(b)30-Aug-00	111010	8.0V (8.57mm$_{p-p}$)	44.8 @2000 mW	4.393	4.812	N/A	111011	8.20V (8.78mm$_{p-p}$)	44.0	4.123	4.067	DispPPOA Tek00001 CompPPPB Tek 00002	128.4	106.7	Not available	Tek00003 2A/div 4.9A
	111100	8.12V (8.7mm$_{p-p}$)	49.0 @1800 mW	4.630	5.028	N/A	111100	8.12V (8.7mm$_{p-p}$)	44.7	4.155	4.125	DispPPOA Tek00001 CompPPPB Tek 00002	134.4	101.55	Not available	Tek00005 2A/div 4.9A
	111100	8.12V (8.7mm$_{p-p}$)	49.9 @1600 mW	4.661	5.081	N/A	111100	8.12V (8.7mm$_{p-p}$)	45.0	4.181	4.155	DispPPOA Tek00001 CompPPPB Tek 00002	135.4	97.6	Not available	Tek00007 2A/div 5.2A

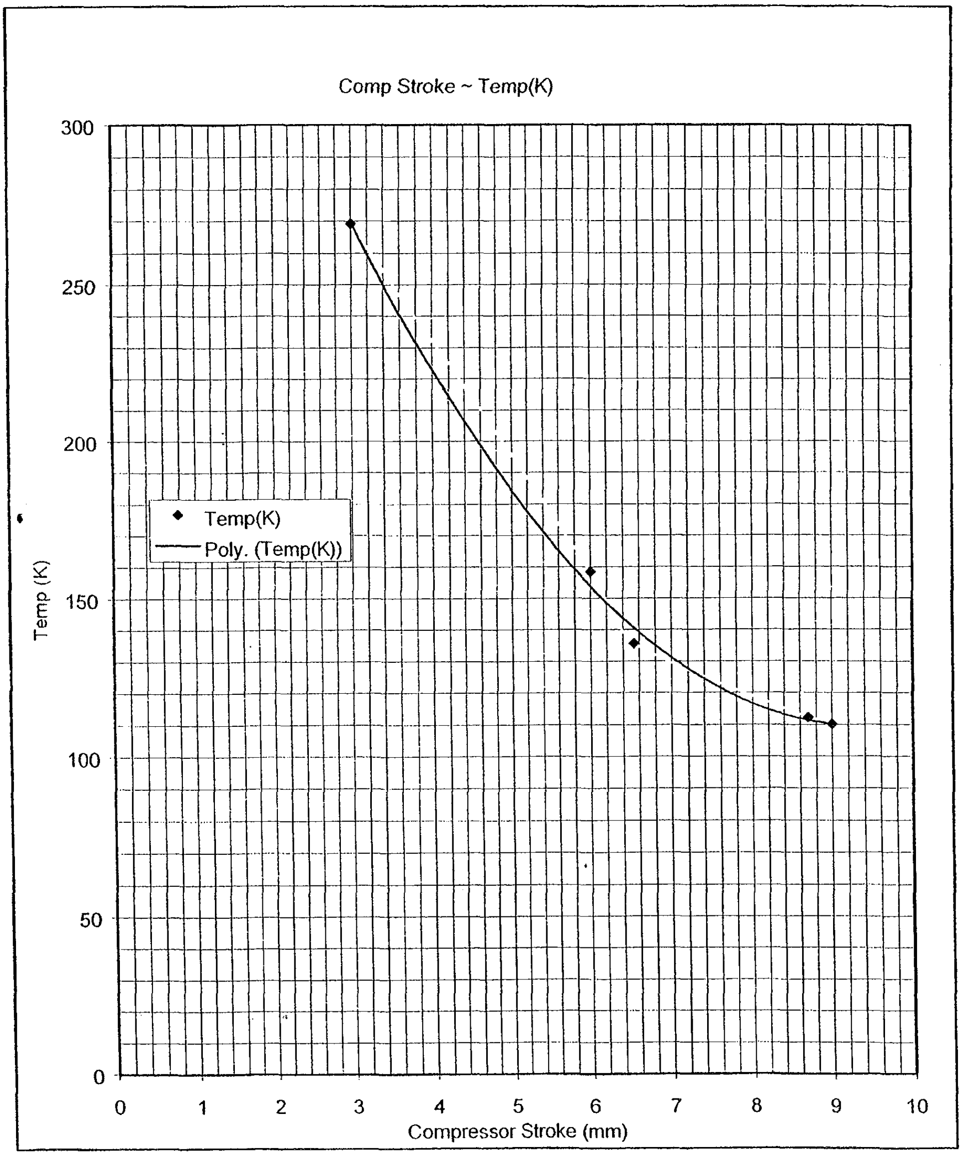
Note: With modified CDE & Cooler setup there is a ratio of PPO(mm) / PPO(Vp-p) = 1.0714. Thus 3mm(p-p) = 2.8Vp-p etc.

Estimated values for equivalent amplitudes, following rework to rescale PPO output

Plot 3(FS CDE ~ FS Coolers)

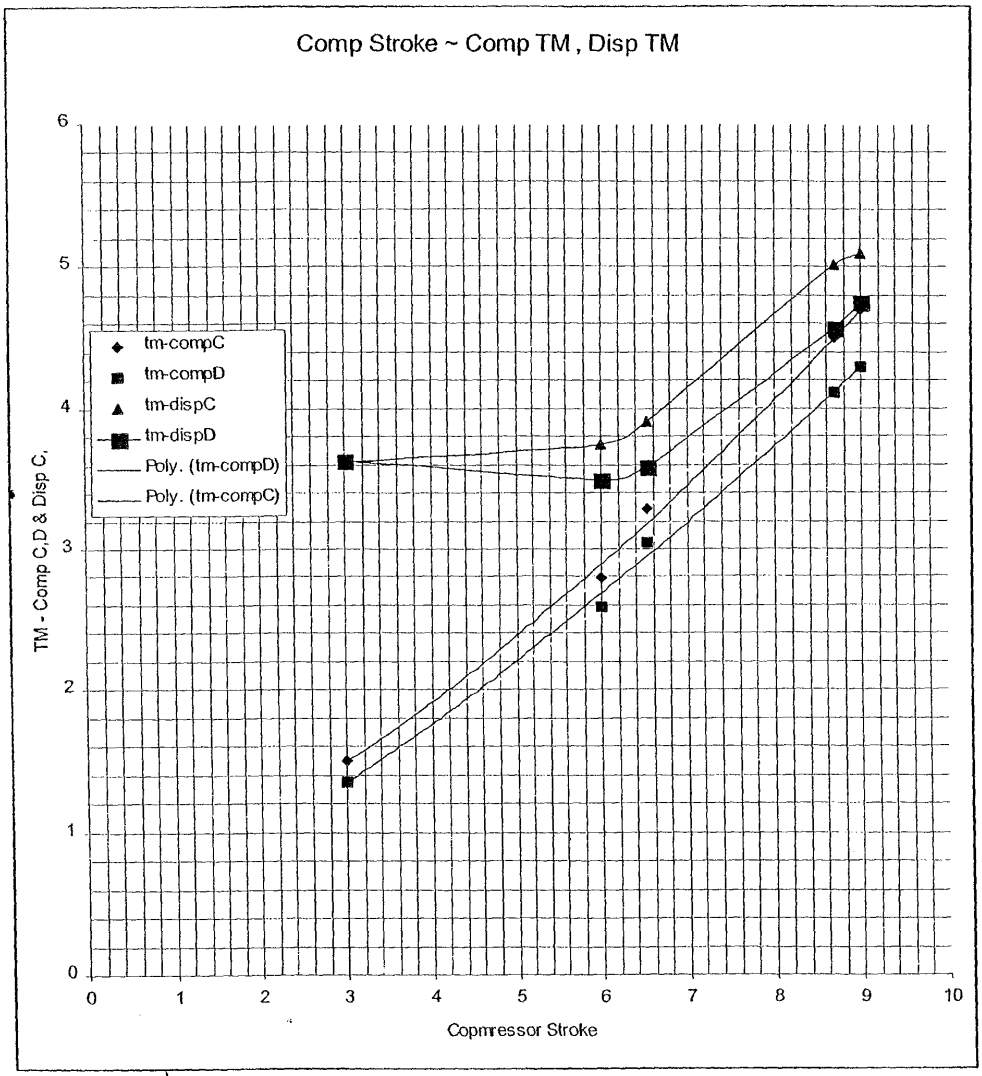


Plot4 (FS CDE ~ FS Coolers)
(FS Coolers (C & D) Stroke ~ Stabilised Cold Finger Temperature



Plot5 (FS CDE ~ FS Coolers)
Compressor / Displacer Stroke vs TM (Volts)

The plot below is for confirmation that the displacers are working properly other wise it does not serve any purpose in measurements but Compressor TM does confirm at stabalised temperature the proportional value of the compressor input Voltage at a given Compressor Stroke.



For the Following tests the FM 1 CDEs are connected to Coolers A and B, and FM 2 CDE is connected to Coolers C and D (heat lift is 2 Watts)

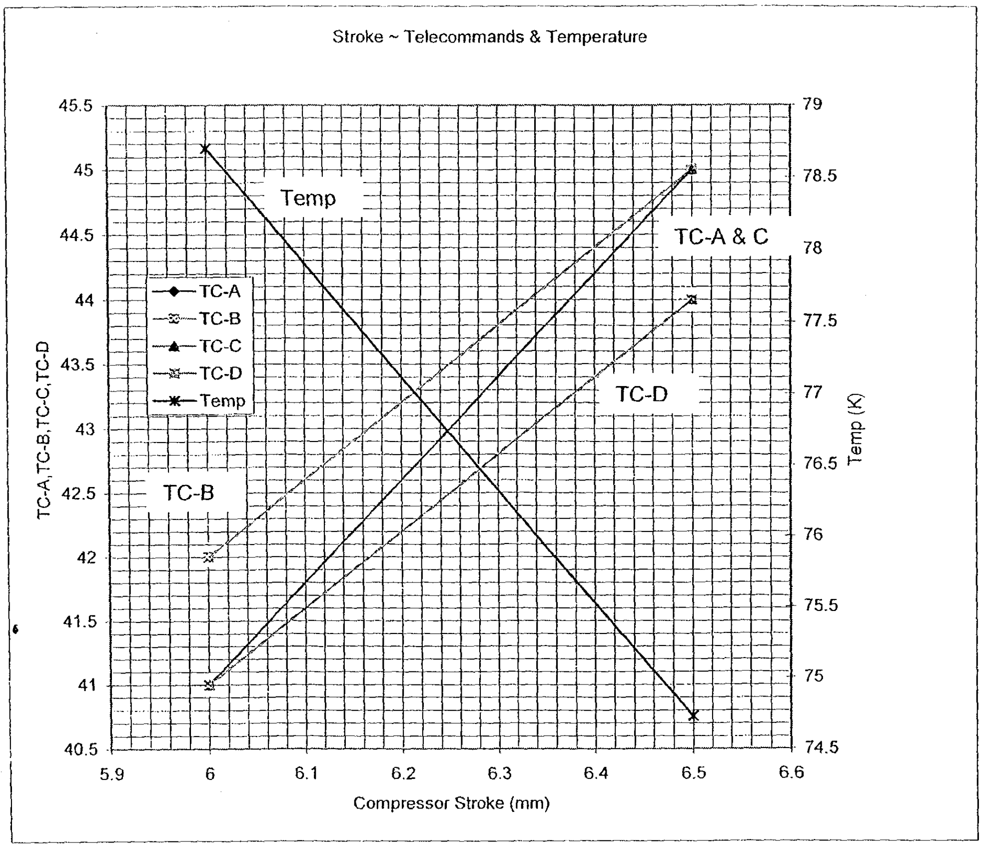
Table 15 Performance Table for FM CDE Operating with FM Coolers

No	TEMP @ 2W LOAD (K°)	Compressor A					Compressor B					Total CDE Input Power Watts
		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		
					Comp (TM) Volts	Disp (TM) Volts				Comp (TM)	Disp (TM)	
1	78.7	101001	6.0	21.1	2.901	3.925	101010	6.0	24.0	3.093	3.736	73
2	78.9	101011	6.26	23.6	3.08	4.03	101010	6.1	23.3	3.10	3.72	76
3	74.73	101101	6.5	27.38	3.26	4.10	101101	6.5	28.25	3.34	3.84	86

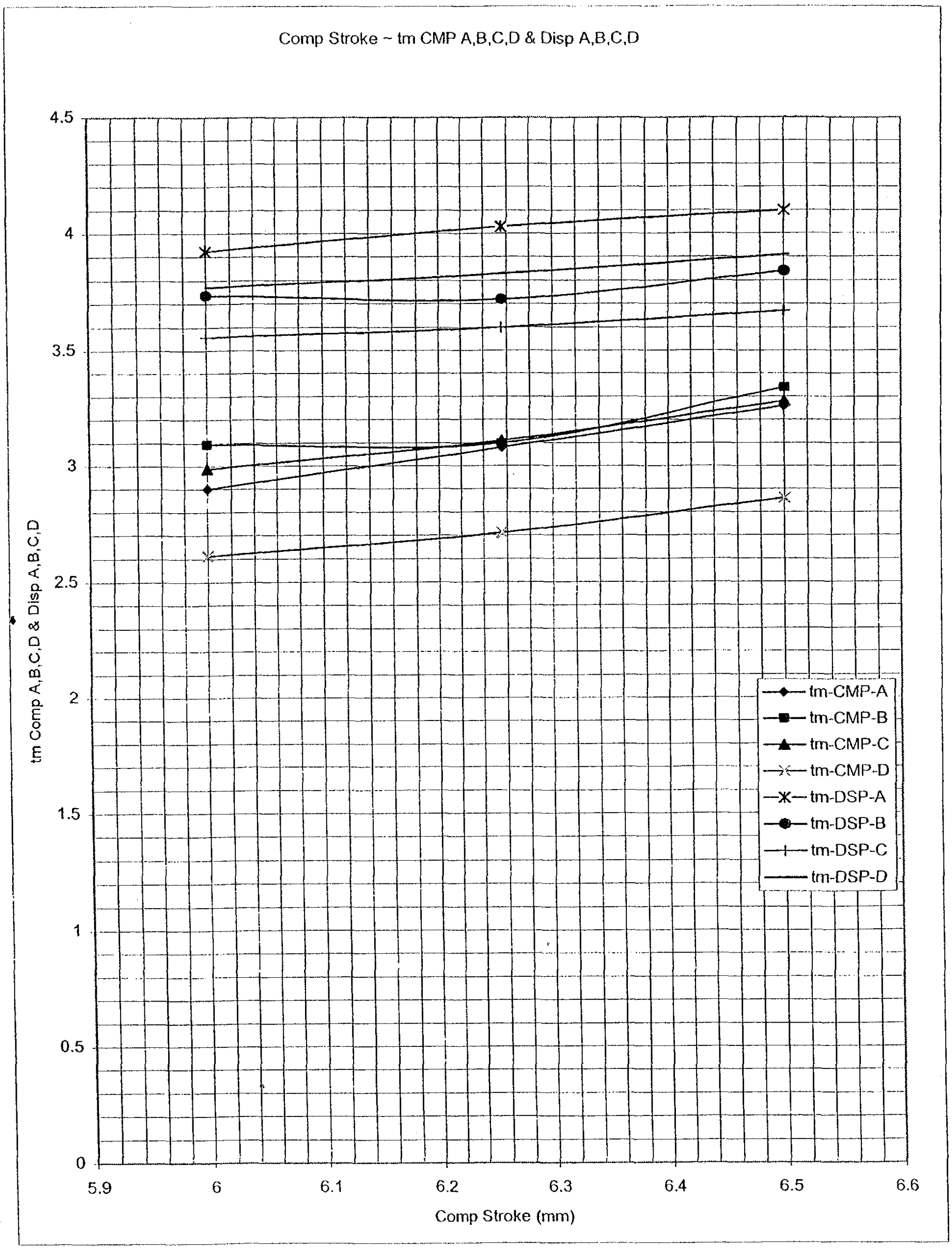
No	TEMP @ 2W LOAD (K°)	Compressor C					Compressor D					Total CDE Input Power Watts
		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		
					Comp (TM) Volts	Disp (TM) Volts				Comp (TM)	Disp (TM)	
1*		101001	6.0	21.2	2.988	3.558	101001	6.0	21.1	2.612	3.77	70
2*		101010	6.26	22.8	3.11	3.60	101010	6.26	23.6	2.71	3.83	74
3*		101101	6.5	26.64	3.28	3.67	101100	6.5	27.41	2.86	3.91	83

The plots given below show the telecommand (decimal) versus stroke (positive slope) and the temperature versus stroke

Plot 6 (FM1,2 CDE ~ FM Spico) At 2 Watts Heat Load



Plot7 (FM1,2 CDE ~ FM Spico) At 2 Watts Heat Load - Stroke vs Tm (Volts)



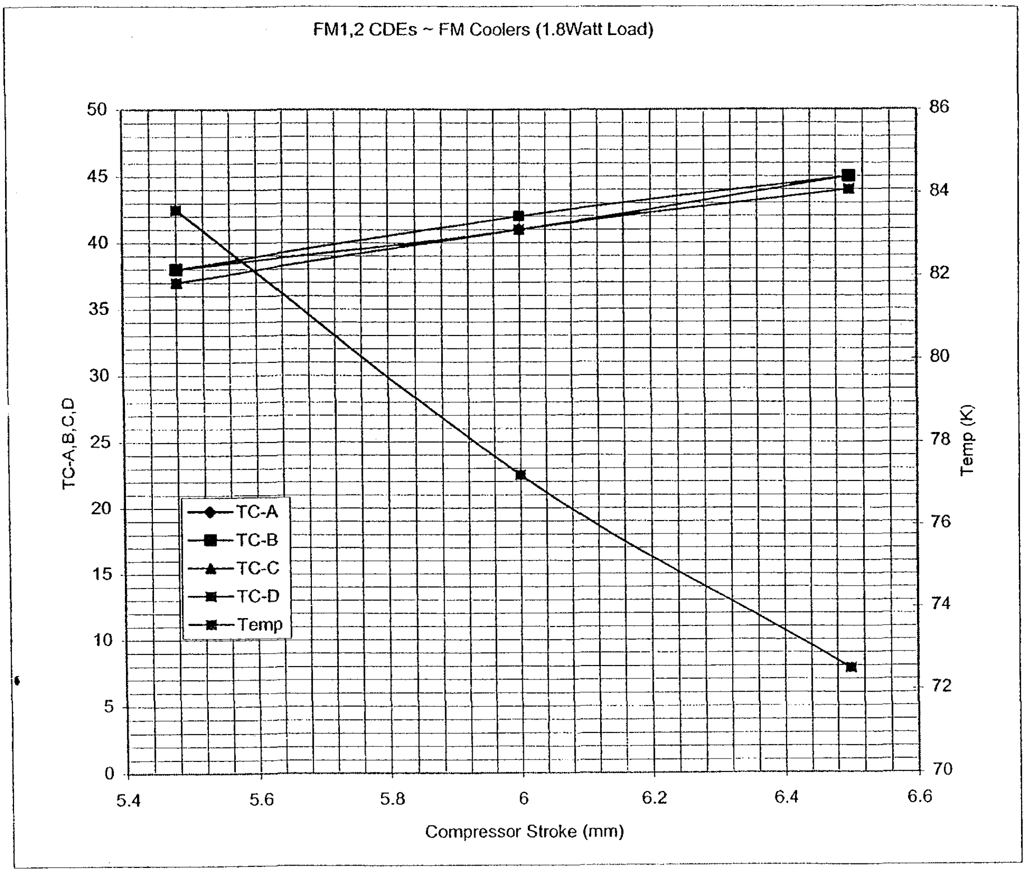
A 1.8 Watt heat load applies for the following table and plots. Spico Coolers A , B are connected to FM1 CDE and Coolers C,D are connected to FM2 CDE.

Table 16 FM1,2 CDE's Connected to FM Spico Coolers @ 1.8Watt

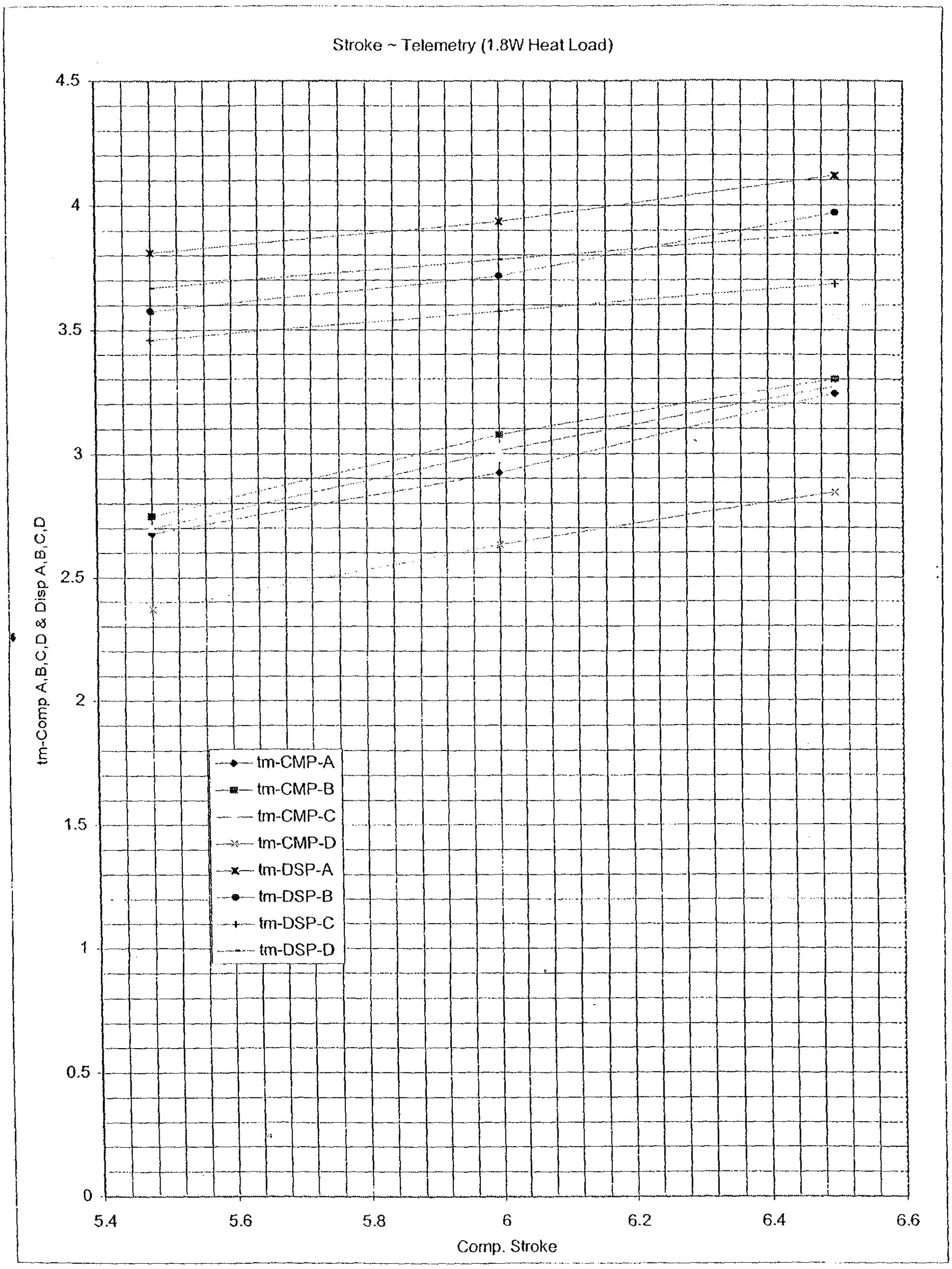
No	TEMP @ 2W LOAD (K°)	Compressor A					Compressor B					Total CDE Input Power Watts
		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		
					Comp (TM) Volts	Disp (TM) Volts				Comp (TM)	Disp (TM)	
1	83.6	100110	5.48	17.8	2.677	3.810	100110	5.48	19.2	2.749	3.576	63
2	77.2	101001	6.0	21.3	2.923	3.935	101010	6.0	24.0	3.075	3.717	71
3	72.5	101101	6.5	26.2	3.243	4.118	101101	6.5	226.9	3.301	3.97	82

No	TEMP @ 2W LOAD (K°)	Compressor C					Compressor D					Total CDE Input Power Watts
		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		
					Comp (TM) Volts	Disp (TM) Volts				Comp (TM)	Disp (TM)	
1*		100101	5.48	17.0	2.700	3.459	100101	5.48	17.3	2.370	3.671	59
2*		101001	6.0	21.4	3.011	3.573	101001	6.0	21.1	2.631	3.782	70
3*		101100	6.5	25.4	3.27	3.685	101100	6.5	25.9	2.844	3.887	80

Plot 8 (FM1,2 CDE ~ FM Spico) At 1.8 Watts Heat Load



Plot 9 (FM1,2 CDE ~ FM Spico) at 1.8 Watts Heat Load – Stroke vs TM (Volts)



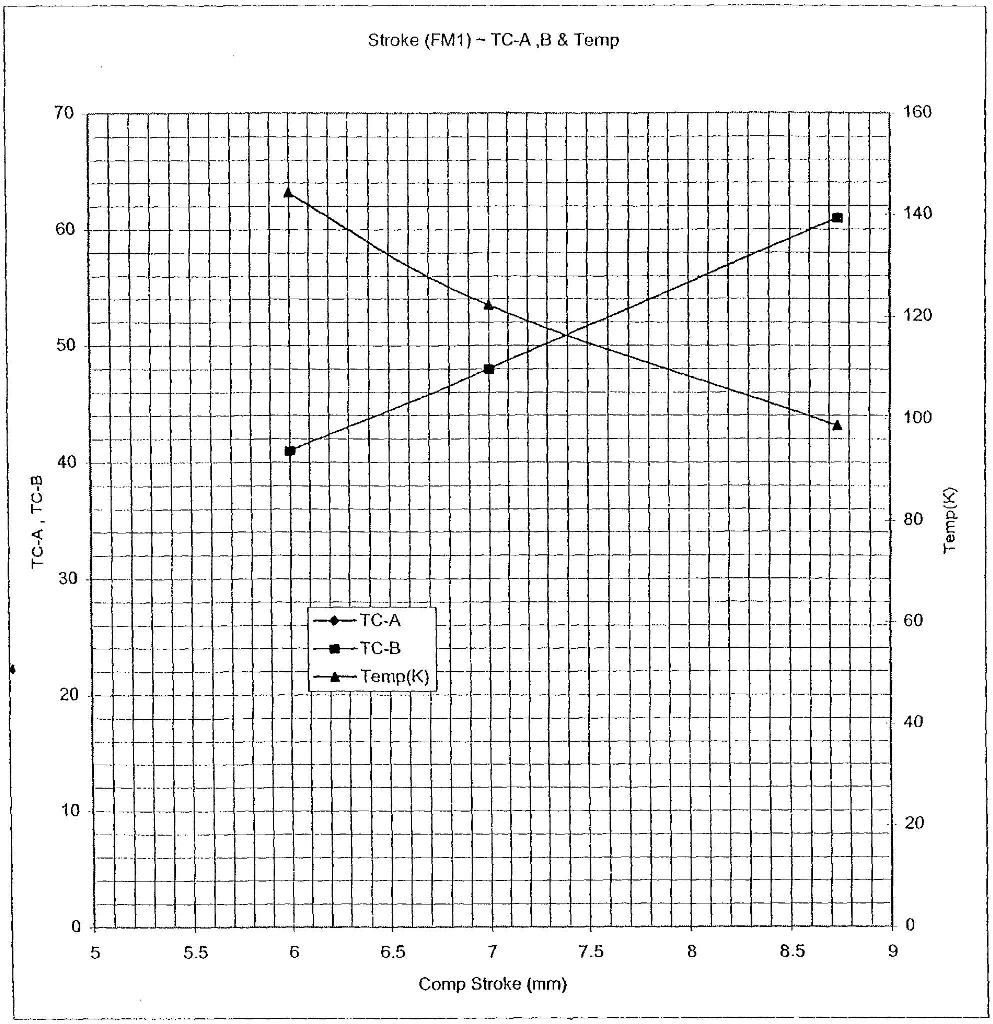
The next set of data is for FM 1 and FM2 CDEs tested with FM Spico Coolers as Individual Pairs.

.

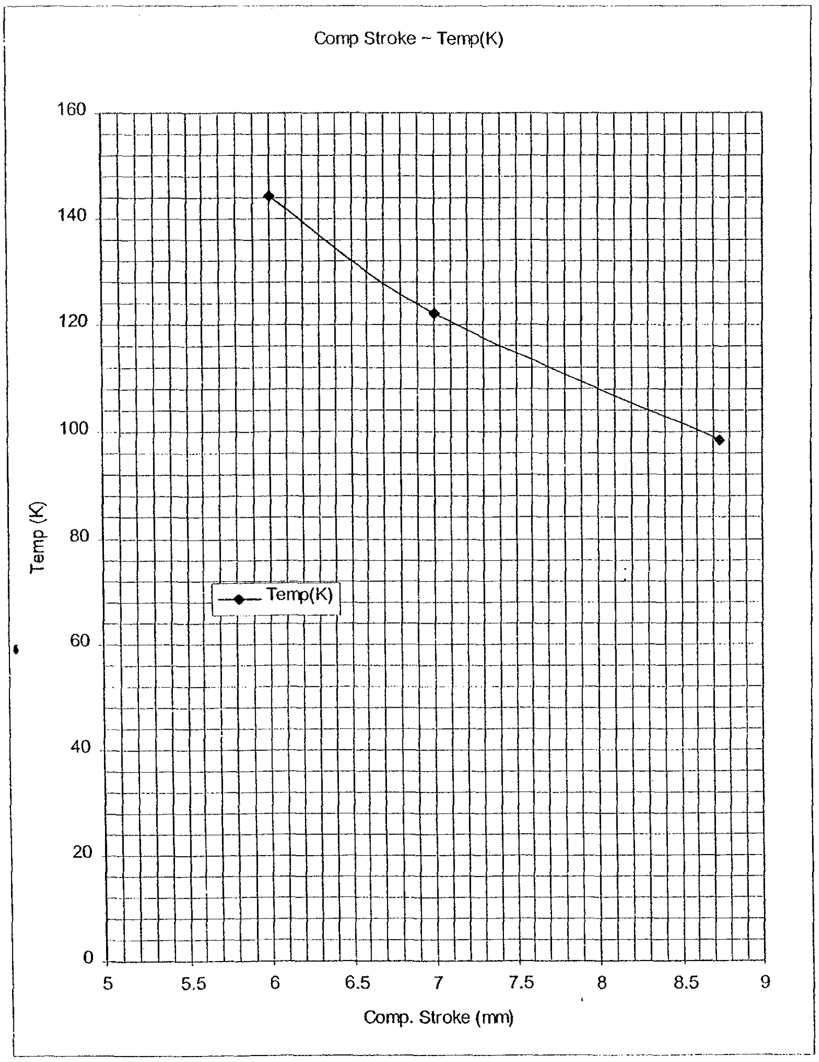
Table 17 FM1 CDE is connected to Coolers A & B for the tests at 2 Watt heat lift

No	TEMP @ 2W LOAD (K°)	Compressor A					Compressor B					Total CDE Input Power Watts
		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry Comp (TM) Volts	Telemetry Disp (TM) Volts	TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry Comp (TM)	Telemetry Disp (TM)	
1	144.4	101001	6	16.4	2.50	3.54	101001	6	17.4	2.53	3.311	58.0
2	122.2	110000	7	24.7	2.99	3.872	110000	7	26.0	3.09	3.613	79.0
3	98.7	111101	8.74	47.1	4.224	5.453	111100	8.53	47.0	4.253	4.83	134

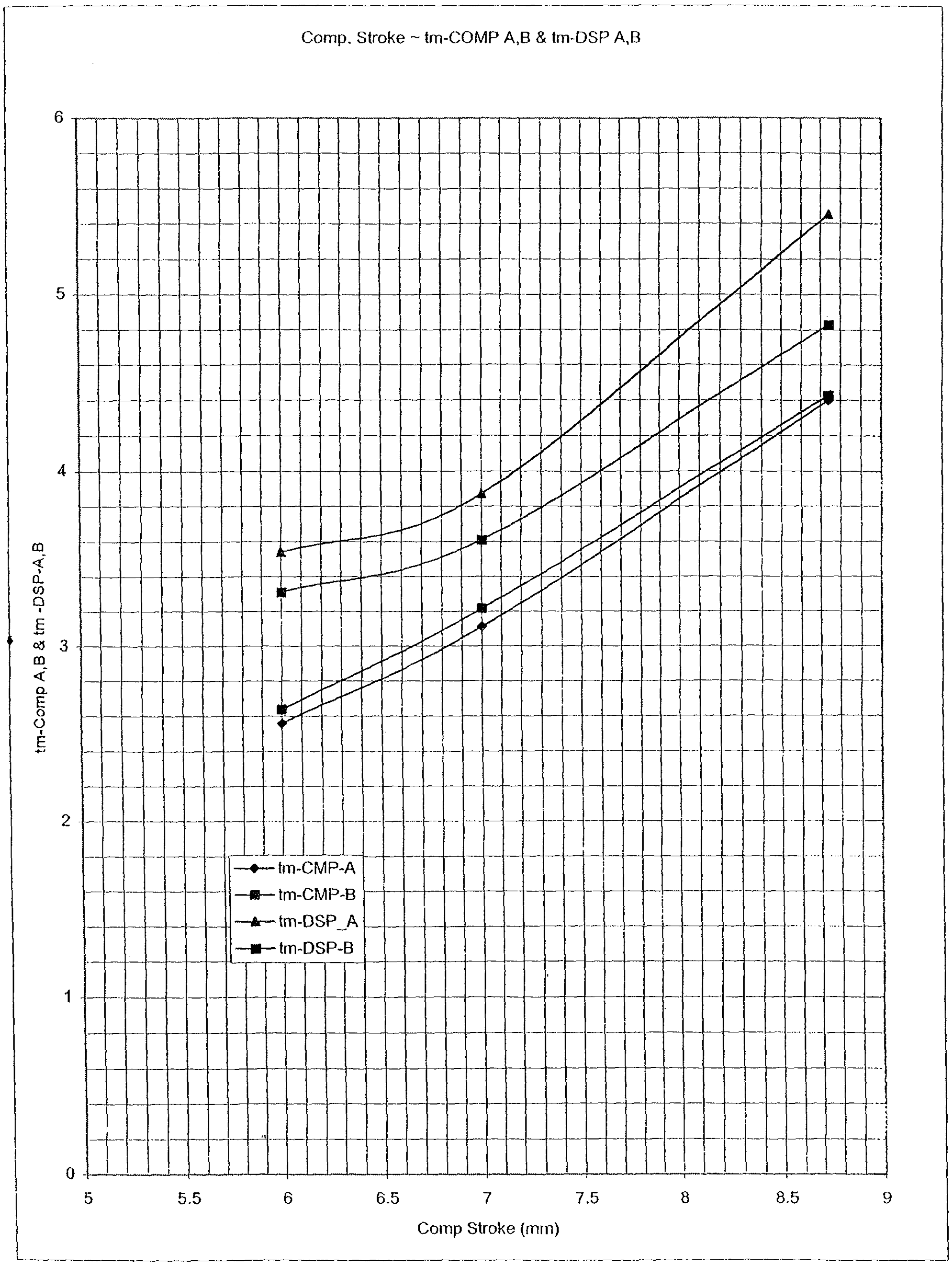
Plot10 (FM1 CDE ~ FM Spico Coolers A & B)



Plot11 (FM1 CDE ~ FM Spico Coolers A & B)



Plot12 (FM1 CDE ~ FM Spico Coolers A & B) - Stroke vs Tm (Volts)

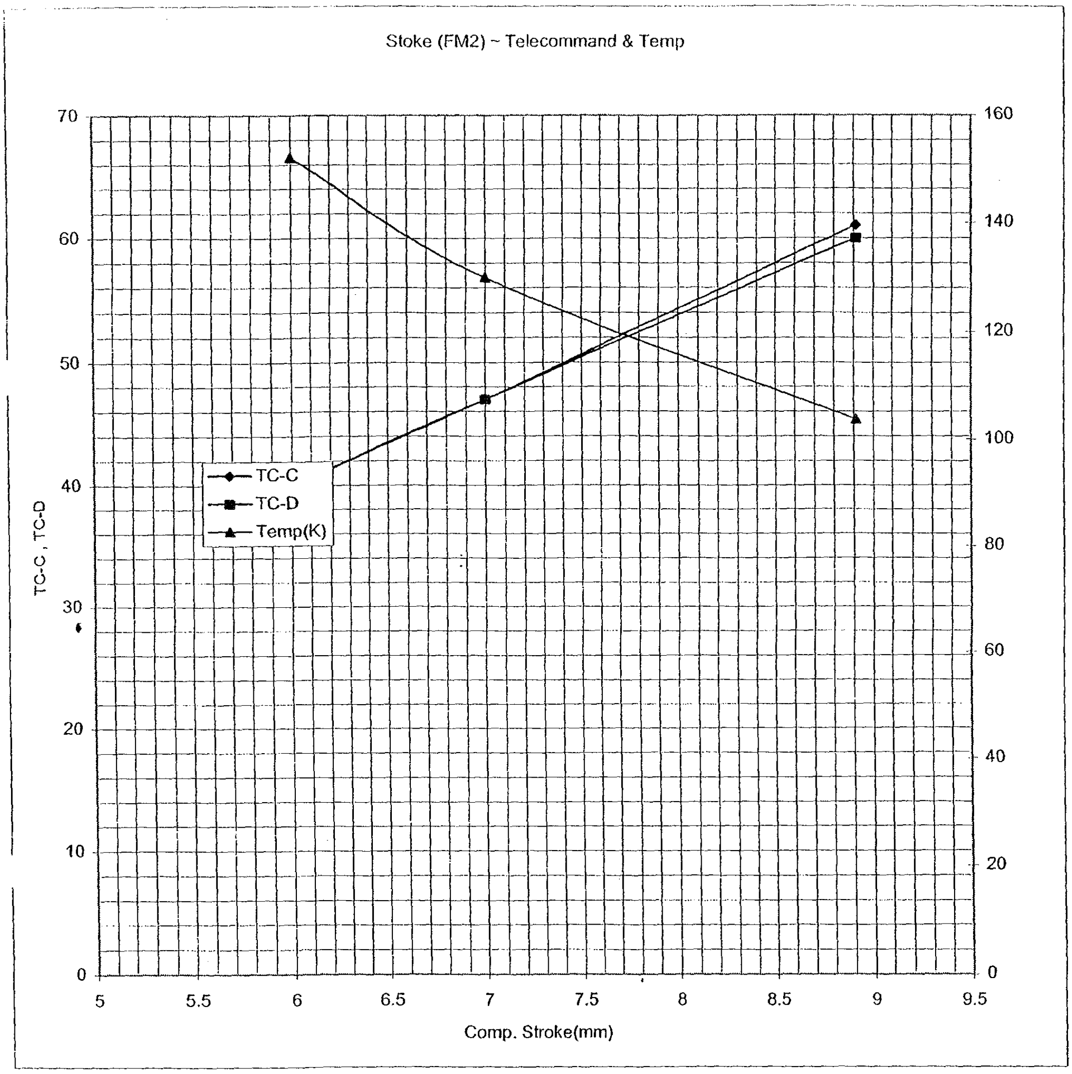


FM2 CDE is connected to Coolers C & D for the following test at 2 Watt heat lift.

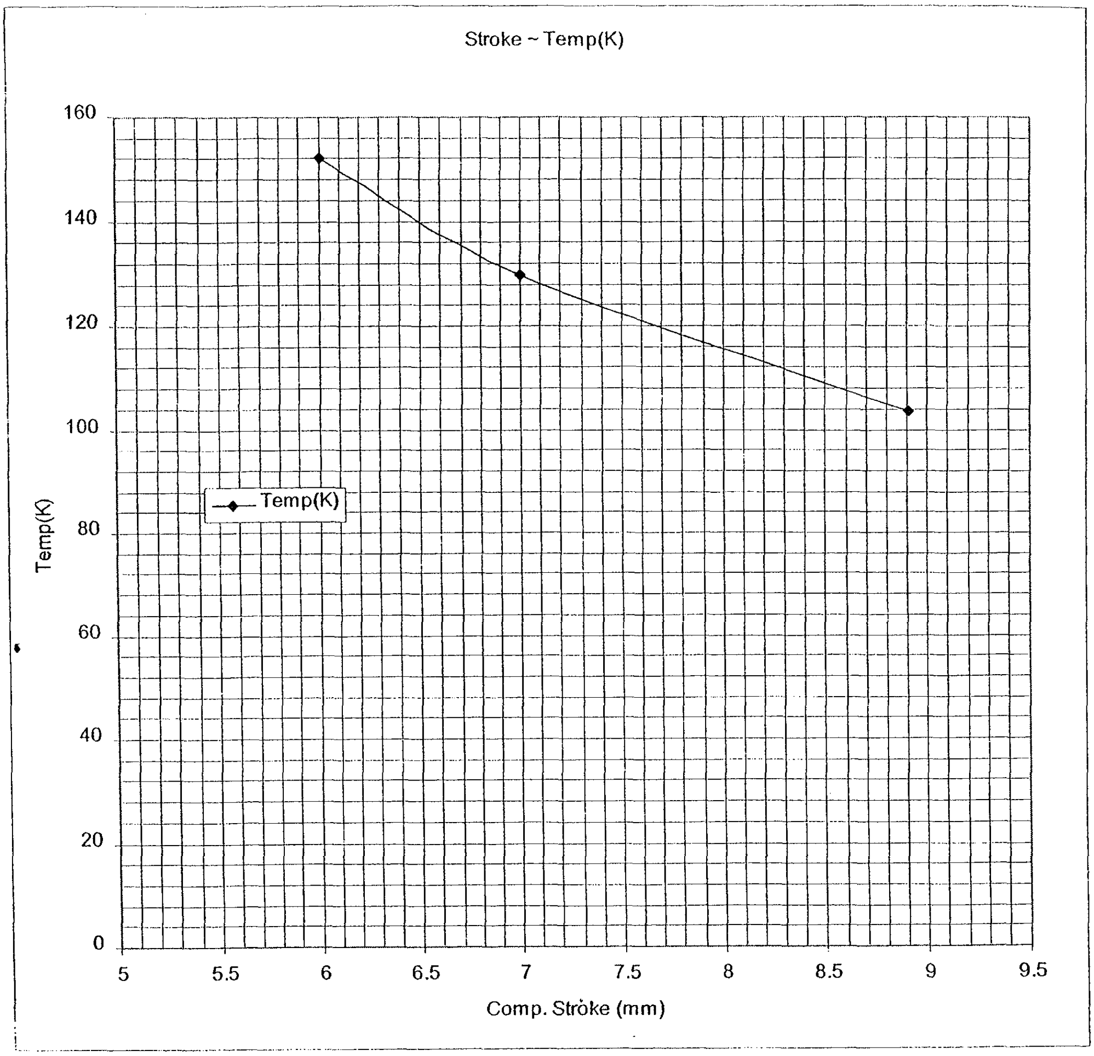
Table 18 FM2 CDE is connected to FM Coolers C & D

No	TEMP @ 2W LOAD (K°)	Compressor C					Compressor D					Total CDE Input Power Watts
		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		TC	PPO (mm)	PWR Watts @ 26.5V	Telemetry		
					Comp TM Volts	Disp TM Volts				Comp TM	Disp TM	
1	152.2	101000	6	15.2	2.431	3.191	101000	6	16.5	2.162	3.382	56.0
2	129.9	101111	7	23.2	2.96	3.425	101111	7	24.6	2.602	3.614	76.0
3	103.7	111101	8.91	47.2	4.398	4.386	111100	8.53	46.5	3.686	4.568	133

Plot13 (FM2 CDE ~ FM Spico Coolers C & D)



Plot14 (FM2 CDE ~ FM Spico Coolers C & D)



Plot15 (FM2 CDE ~ FM Spico Coolers C & D) - Stroke vs TM(Volts)

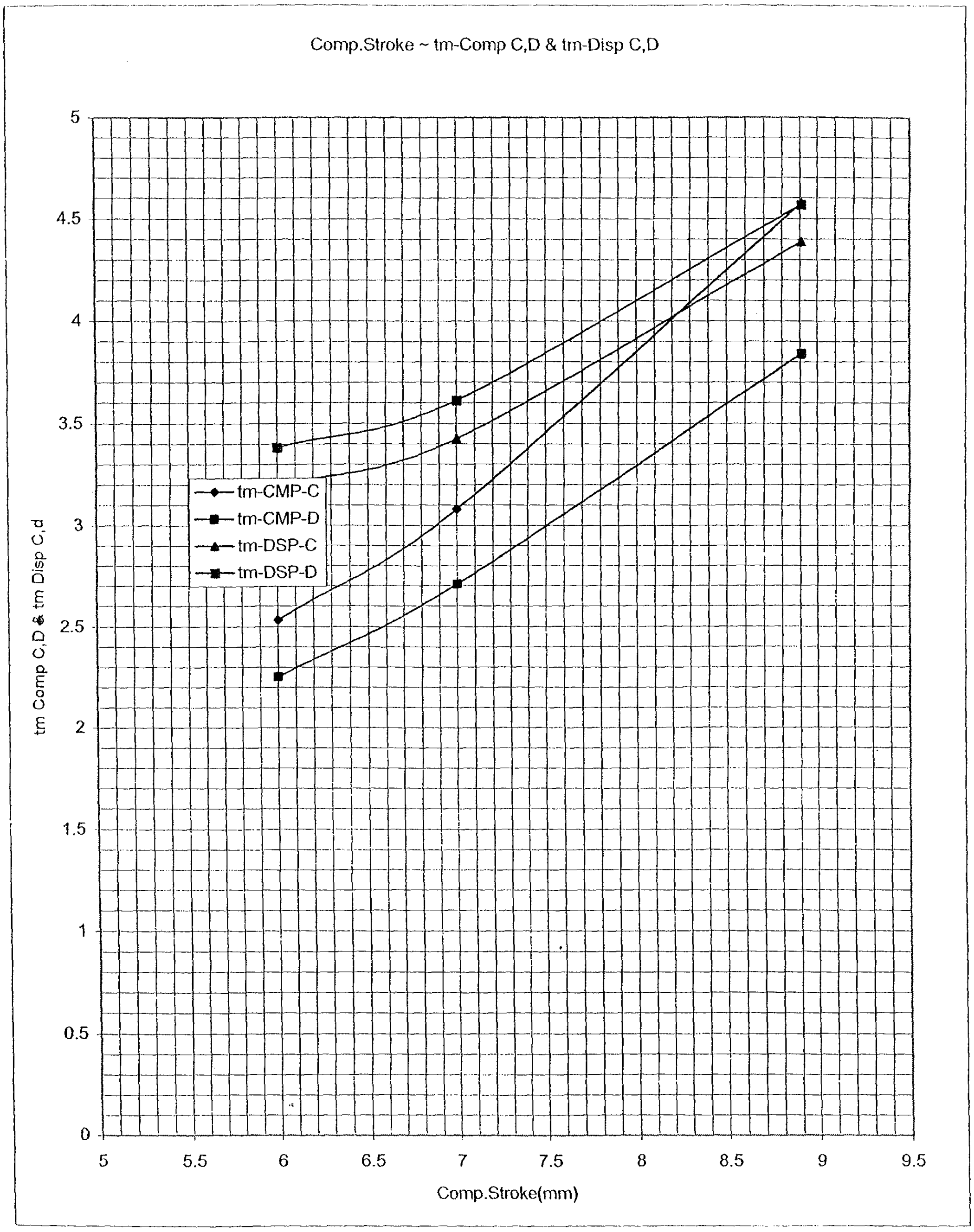


Table 19 Decimal To Binary Conversion Table

Table19 (Dec)	Binary MSB.......LSB	Dec	Binary MSB......LSB	Dec	Binary MSB.........LSB
0	000000	22	010110	44	101100
1	000001	23	010111	45	101101
2	000010	24	011000	46	101110
3	000011	25	011001	47	101111
4	000100	26	011010	48	110000
5	000101	27	011011	49	110001
6	000110	28	011100	50	110010
7	000111	29	011101	51	110011
8	001000	30	011110	52	110100
9	001001	31	011111	53	110101
10	001010	32	100000	54	110110
11	001011	33	100001	55	110111
12	001100	34	100010	56	111000
13	001101	35	100011	57	111001
14	001110	36	100100	58	111010
15	001111	37	100101	59	111011
16	010000	38	100110	60	111100
17	010001	39	100111	61	111101
18	010010	40	101000	62	111110
19	010011	41	101001	63	111111
20	010100	42	101010		
21	010101	43	101011		

17. CALIBRATION

The Compressors within the Cooler System demand high peak currents in order to provide the required cooling. At any given drive power to the compressors, there is a fixed input power to the CDE. The nominal input current will occur at a supply voltage of 28 Volts, but if this voltage drops due to excessive lead length or high resistivity of the supply leads, then the supply current will increase. (the CDE has a negative incremental input impedance). The system has been calibrated at Astrium using a standard set up with a nominal input voltage of 26.5 Volts as requested. The calibration allows the various powers within each part of the system to be known and allows comparison with other models since all Astrium cooler systems to date use the same test equipment and lead lengths. Therefore if the configuration is different to that given above (Section 13), the figures given in the performance table will be different to those measured at Astrium and may indicate that more power is needed for a given stroke. **However, when the piston is operating at a certain stroke, the telemetry will provide the correct reading irrespective of test set up.** If a different setup is used a re-calibration with the new system will be required for consistency.

18. RECOVERY PROCEDURE

This section discusses the steps to be taken in the case of an in-flight failure of the cooler system.

It is assumed that an in-flight failure will manifest itself either by excessive current being taken from the input power bus or by severe degradation of the cooling performance of the system.

Each CDE has its power fed from two separate busses each containing a latching current limiter (LCL). The relay within the CDE allows the compressors to be fed from either one bus (nominal mode) or two busses (backup mode). In the case of excessive power being taken, power down both CDEs and configure their relays such that each compressor is fed from a separate LCL. By switching into circuit each LCL in turn. and commanding the associated cooler to nominal running mode, the failure can be isolated to one particular cooler system.

If only one LCL needs to be switched out of circuit, then a three cooler system could be used. However, this configuration is not advised, since vibration cancellation is now not possible resulting in a vibration which may effect the satellite's control system.

If the failure is in the power input circuit or low voltage power supply, two LCLs will have to be switched out of circuit (ie both supplies to one CDE). In this latter case it is impossible to use a three cooler system and the back up mode will need to be entered using one CDE configured as a Master.

In the case of degraded cooler performance but with no obvious excessive current being taken, the offending cooler system can be deduced by observing the output of the Compressor Drive Telemetry and comparing them with the values before the failure occurred. Disabling the faulty cooler system would be a possibility if the failure was due to a mechanism, but if it was due to an electronic component failure, the fault may evolve and cause excessive current to be drawn. Since there is no way to deduce exactly where the failure occurred, it is advised that one CDE system be used in backup mode.

Finally, if the link between the master and slave is lost it is possible to make the old master a slave and vice versa.

Three flow charts are shown below which detail the steps to be taken to implement a recovery procedure. shows how to reconfigure the system in order to change the master to a slave and vice versa. Figure 1 gives the Power Up sequence in Back Up mode (Power Down from Nominal mode is given in of Section 11) and Figure 1 gives the flow diagram for setting the amplitude of the stroke in Back Up mode.

(The CDE and mechanisms must reach their nominal operating temperatures before these procedures are implemented).

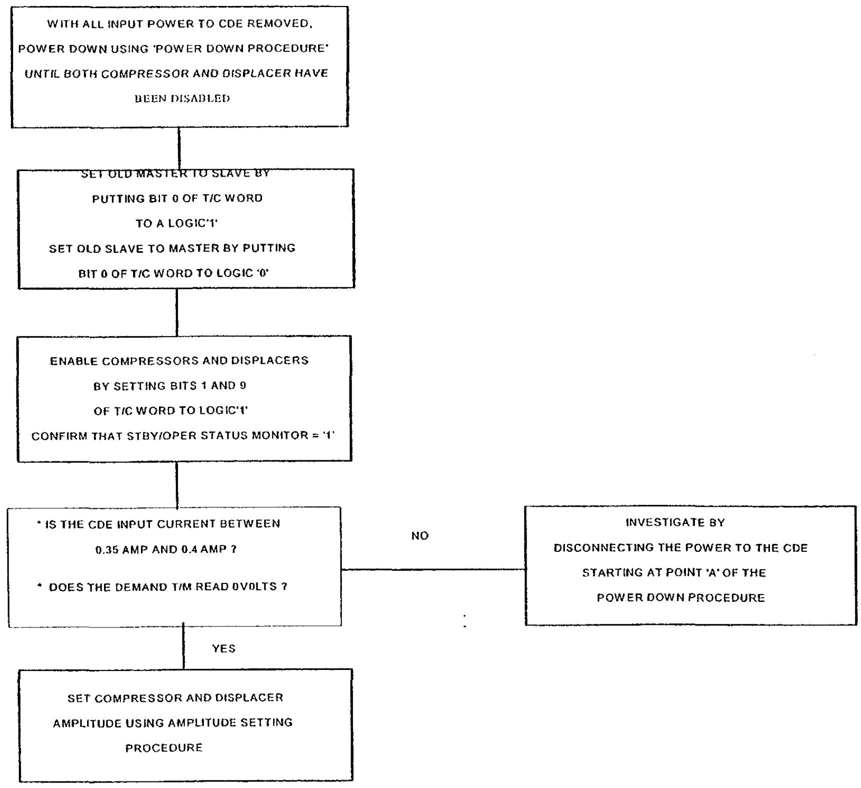


Figure 12 Flow Diagram to Exchange a Master CDE to a Slave and Vice Versa

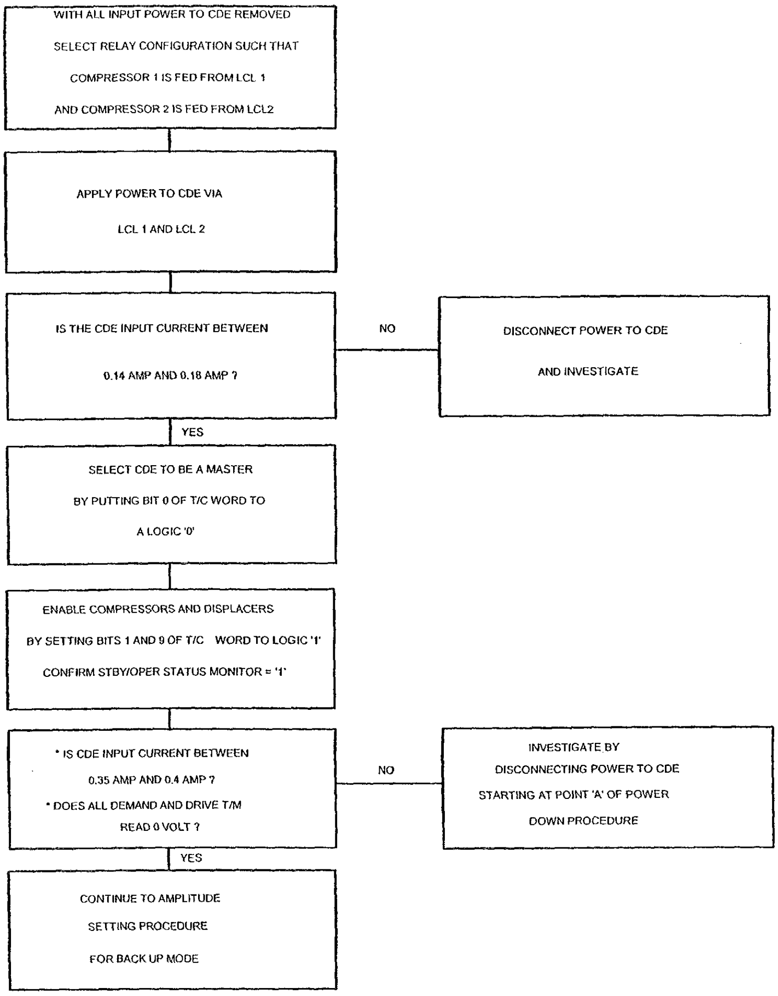


Figure 13 Flow Diagram for Power Up Back Up mode

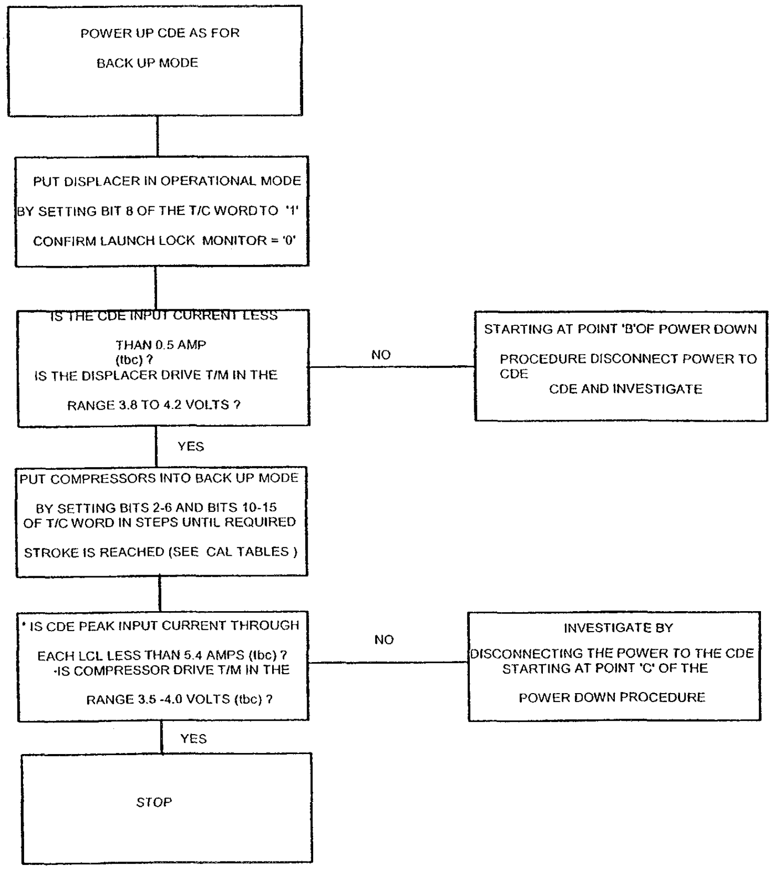


Figure 14 Flow Diagram Showing How to Set the Amplitude in Back Up Mode

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DOCUMENT CHANGE DETAILS

ISSUE	CHANGE AUTHORITY	CLASS	RELEVANT INFORMATION/INSTRUCTIONS
1			
2	INT0033		MIN-INTCC-MMS-0018-00. Destroy Issue 1 and replace with Issue 2
3			INT.MAN.CDE.0123.MMB Issue3 is superceded by Issue4
4	INT0090		TM graph x axis update and minor additions

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