Operating Instructions for C3F8 Supply Lines

This manual gives instructions for purging, evacuating, and filling the C3F8 cooling system, and connecting/disconnecting discs to the cooling system.

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History of Changes

Rev. No.	*Date*	*Pages*	*Made by*	*Description of changes*
A	28/4/04	All	NP Hessey	Original document
B	28/7/04	Many	NP Hessey	Safety warnings + dP protection + new fig. 1 etc.
C	26/1/05	Many	NP Hessey	V13 and 14; many small improvements learnt from experience.

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Introduction

This document gives instructions for operating the C3F8 cooling system for the ATLAS SCT Discs. The cooling system can broadly be split into four components: the C3F8 Cooling Plant ("C3F8 Plant"), the supply and return lines with their associated valves, vacuum system, purge lines etc. ("Supply Lines"); the disc test box ("Disc Box"); and the cylinder test box ("Cylinder Box"). Figure 1 shows how the supply lines interconnect the cooling plant with the test boxes, and labels the valves with the names used in this document.

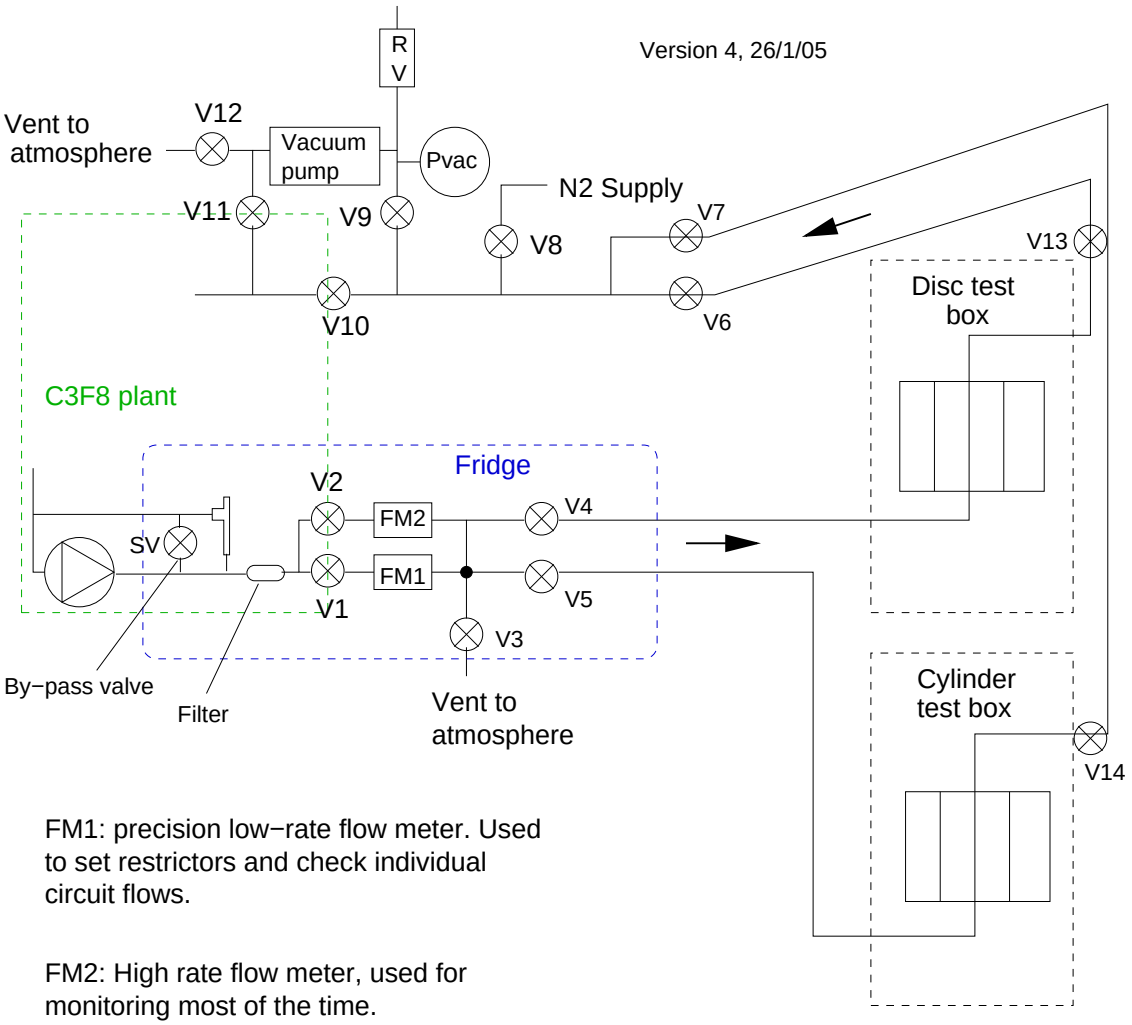

Figure 1: Supply lines between C3F8 Plant and Test Boxes, with valve labels.

Certain operations can cause damage to equipment, loss of C3F8 (which is expensive and bad for global warming), or risk of personal injury. Hence it is important to follow the instructions closely. Use gloves to avoid contact with cold surfaces. Use goggles if there is a risk of C3F8 escape, especially relevant if adjusting the restrictors.

Once the Cooling Plant and Supply Lines are ready for use, they have to be filled with C3F8.

This requires a sequence of operations detailed below: Operation 1 (Flush lines with nitrogen); Operation 2 (Evacuate lines to atmosphere); Operation 3 (Fill plant with C3F8).

Thereafter each time a disc is put in a circuit Operation 4 (Preparing for Disc Cooldown) has to be carried out.

Each time the disc tests are finished, Operation 5 (Preparing for Disc Removal) has to be carried out before removing a disc or opening its cooling circuits.

In the event of problems with the C3F8 Plant or the Supply Lines, and at the end of all tests, the C3F8 has to be removed from the system. Operation 6 (Final Removal of C3F8) achieves this.

For all operations, start the DCS and make sure at least one inlet and one outlet electro-valves are open to the differential pressure sensor: this will avoid putting too large a pressure across it.

Valves V13 and V14: these were added later, and are not mentioned in the instructions. They should generally be left open. They are for the specific purpose of leak checking the on-disc cooling circuits: by reducing the closed-off volume, they make the check more sensitive.

1 Operation 1: Flush With Nitrogen

Initial state: Compressor off; liquid pump off; vacuum pump off; C3F8 Plant, Supply Lines, and any disc circuits full of air at atmospheric pressure. N_2 bottle closed.

If preparing for initial C3F8 fill, connect the C3F8 bottle to the schraeder valve first, with the bottle-valve closed. Then the connecting tube is also purged with N2 and evacuated.

Step	Action	Result/Comments
1	Close V4, V5, V6, V7	Disc Box and Cylinder Box isolated from system
2	Close V9, V11, V12	Vacuum pump isolated from system
3	Open V1, V2, V3, V10 and SV in C3F8 plant	Flush circuit is open and at atmospheric pressure
4	Set nitrogen pressure regulator to 0 bar (anti-clockwise); Open V8; slowly raise regulator pressure till you hear gas flowing	Flushing begins (gently, avoiding damage to flow meters)
5	Wait till flushed	Circuit is full of dry nitrogen at atmospheric pressure
6	Close V8 then V3 immediately after	Flushing stops; circuit is sealed

Final state: The circuit is full of dry nitrogen, sealed from the atmosphere.

Note: Leak checks can be carried out by pressurising the lines via V8 with V3 closed, and watching how fast the pressure drops. Make sure the circuit is leak-tight before proceeding.

2 Operation 2: Evacuate lines to atmosphere

Initial state: Compressor off, liquid pump off, vacuum off; circuit full of dry nitrogen at atmospheric pressure; V3, V4, V5, V6, V7, V8, V9, V11, V12 closed; V1, V2, V10 open; i.e. following Operation 1.

DO NOT CARRY OUT THIS OPERATION WITH C3F8 IN THE SYSTEM!

Step	Action	Result/Comments
1	Check all valves are in the appropriate initial state	Safety of flow meters, vacuum pump etc.
2	Check Pvac is about 1 bar absolute; if above, open V3 briefly to bring down to 1 bar; if below, open V8 briefly to top up with dry nitrogen	Avoid putting excess pressure on vacuum pump
3	Close V1 and V2	Prevent reverse flow through flow meters
4	Open V12 and turn on the vacuum pump	Inlet side of vacuum pump pressure drops
5	Open V9	Circuit evacuation starts
6	Wait till Pvac and other pressure meters show circuit is evacuated (about 1 mbar)	Circuit is evacuated with remnant dry nitrogen
7	Close V12 and V9 then turn vacuum pump off	

Final state: C3F8 Plant and Supply Lines are at vacuum from V6/V7 to V1/V2, with 1 mbar dry nitrogen. Circuit lines from V1/V2 to V4/V5 have nitrogen at 1 bar. Circuit lines from V4/V5 to V6/V8 unchanged.

The circuit can again be checked for leaks by watching how fast the pressure rises. Do not proceed until the circuit is leak tight.

3 Operation 3: Fill Plant With C3F8

Initial state: Compressor off, liquid pump off, vacuum off; circuit full of dry nitrogen at vacuum of 1 mbar; V1, V2, V3, V4, V5, V6, V7, V8, V9, V11, V12 closed; V10 open. C3F8 bottle on scales, connected to schraeder valve, with bottle valve closed. I.e. following Operation 2.

Step	Action	Result/Comments
1	Record weight of C3F8 bottle	So you know when to stop.
2	Check/put (safely) all valves are in the appropriate initial state	Safety of flow meters, vacuum pump etc.
3	Check Pvac is low (below 30 mbar on DCS)	Do not waste C3F8 by mixing it with moist air etc.
4	Close V10	Isolate C3F8 Plant from supply pipes
5	Open valve on C3F8 bottle.	C3F8 Plant is full of C3F8 gas at about 6.9 bar g
6	Turn on compressor (separate instructions), cool HE1 to minimum temperature (See C3F8 plant instructions)	C3F8 evaporates in bottle and condenses in HE1.
7	Watch weight of C3F8 bottle. When desired amount (3 kg = 2 l) transferred, close valve on C3F8 bottle	Desired quantity of C3F8 is in the C3F8 Plant
8	Remove C3F8 tube from schraeder valve, replace seal on valve.	Bottle can be removed to storage
9	Turn compressor off	C3F8 pressure rises slowly to about 6.9 bar g.

Date	Time	Weight (kg)	Comments
21/10/04	85.5	09:00	Start cooling and open valve
21/10/04	82.5	09:45	Close bottle valve

Table 1: Bottle weight history

4 Operation 4: Preparing for Disc Cooldown

In the following, V4, V6 and V13 apply to the Disc Box; V5, V7 and V14 apply to the Cylinder Box.

4.1 Operation 4.1: Flushing with Nitrogen

Initial state: Compressor off, liquid pump off, vacuum pump off; C3F8 Plant full of warm C3F8 at about 6 bar; supply lines full of air at pressure of 1 bar; **disc cooling circuits connected up and sealed**; unused cooling circuits in test boxes sealed off; V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, V11, V12 closed.

Step	Action	Result/Comments
1	Check all Supply Line valves are closed and supply lines on disc-side of V1, V2, V10 have no C3F8 in (or maximum 1 mbar C3F8 as after Operation 5)	Avoid loss of C3F8 to atmosphere
2	Open (V4 and V6) or (V5 and V7)	Circuit is open for flushing
3	N_2 regulator to 0; Open V8; slowly raise N_2 regulator to high pressure (e.g. 19 bar g); close V8	Allows leak check: see how quickly the pressure drops. Probably want to close inlet valves on disc and V13 or V14.
4	Open V3	Vent the nitrogen to atmosphere
5	Set nitrogen regulator to about 2 bar and open V8	Flushing starts. Note the disc circuits are flushed “backwards”
6	Wait for sufficient flushing	Supply Lines and disc cooling circuits are full of dry nitrogen
7	Close V8 followed soon after by V3	Flushing stops; circuit is sealed

Final state: C3F8 Plant is full of warm C3F8; Supply Lines and disc circuits are full of dry nitrogen at about atmospheric pressure.

Do not proceed until the circuit is leak tight.

4.2 Operation 4.2: Evacuating to Atmosphere

Initial state: Compressor off, liquid pump off, vacuum pump off; C3F8 Plant full of warm C3F8 at about 6 bar; Supply Lines and disc circuits full of dry nitrogen at about atmospheric pressure; unused cooling circuits in test boxes sealed off; V1, V2, V3, V8, V9, V10, V11, V12 closed; for disc in Disc Box, V4 and V6 open, V5 and V7 closed; for disc in Cylinder Box V5 and V7 open, V4 and V6 closed.

Step	Action	Result/Comments
1	Check (Pvac) system is at about atmospheric pressure with dry nitrogen; all valves are in correct initial state.	Avoid putting excess pressure on vacuum pump and wasting C3F8
2	Open V12, turn vacuum pump on, open V9	Start evacuating nitrogen from lines to atmosphere
3	Wait till pressure is about 1 mbar	Circuit is evacuated with residual dry nitrogen
4	Close V9, turn the vacuum pump off, close V12	Vacuum pump is isolated from Supply Lines
5	Leak Check	Make sure all leaks are cured before introducing C3F8

Final state: lines are leak tight, with about 1 mbar of dry nitrogen.

4.3 Operation 4.3: Filling with C3F8

Initial state: Compressor off, liquid pump off, vacuum pump off; C3F8 Plant full of warm C3F8 at about 6 bar; supply lines and disc circuits at or below 1 mbar with residual dry nitrogen; unused cooling circuits in test boxes sealed off; V1, V2, V3, V8, V9, V10, V11, V12 closed; for disc in Disc Box, V4 and V6 open, V5 and V7 closed; for disc in Cylinder Box V5 and V7 open, V4 and V6 closed.

Step	Action	Result/Comments
1	Check pressure is below 30 mbar in DCS with all valves in correct initial state	Avoid excess pressure on vacuum pump and avoid wasting C3F8
2	Partially open V10 slowly.	7 bar C3F8 to vacuum! Discs fill with C3F8; flow-meters fill backwards, slowly via restrictors.
3.	Open V10 fully.	
4.	Open SV	By-pass liquid pump.
5.	Open V1 or V2, depending on which flow-meter is wanted	Cooling circuit is open, ready to start cooling

Final state: C3F8 Plant, Supply Lines, Disc circuits are full of warm C3F8 at about 6 bar. Circuit is ready for cooling, with flow via required flow meter.

5 Operation 5: Evacuating C3F8 to Plant and Preparing For Disc Removal

Initial state: Cooling running (Compressor on; liquid pump on); vacuum pump off; disc in place full of C3F8; Either V1 or V2 open, the other closed; either V4 and V6 or V5 and V7 open, the other two closed; V10 open; V3, V8, V9, V11, V12 closed.

Make sure all cooling circuit components (including the heat exchangers) in the Disc or Cylinder Box are open for coolant flow.

Do not leave unattended while evacuating! If cooling machine trips off, the pressure in the vacuum pump rises very quickly, unless V10 and V11 are quickly closed off.

Step	Action	Result/Comments
1	Turn off all power to the disc	Cooling no longer needed.
2	Close V2 or V1 (so both are closed)	C3F8 supply to disc stopped
3	Open SV	Keep C3F8 circulating via by-pass – cools C3F8 better
4	Turn R404 set-point temperature to the minimum possible	C3F8 in HE1 cools down further, pressure in circuits drops, C3F8 in circuits evaporates and condenses in HE1
5	Wait till disc has warmed up	Discs warms up when all C3F8 has evaporated: now there is no more liquid in the circuits, only vapour at about 1 bar if HE1 is at -36 °C
6	Make sure V12 is closed and Pvac is low (below 2 bar a on DCS, 1 bar g on P_{VAC})	Avoid C3F8 loss and protect vacuum pump
7	Open V9 and V11 and close V10	Put vacuum pump in circuit
8	Turn vacuum pump on	Start evacuating Supply Lines and disc circuits, returning C3F8 gas into C3F8 Plant
9	Wait till Pvac is low enough (below 30 mbar in DCS)	Very little C3F8 left in lines
10	Close V11	C3F8 secured in C3F8 plant
11	Close V9 and turn off vacuum pump	Vacuum pump isolated from circuit
12	Turn off compressor	C3F8 in Plant will slowly warm up and reach 6 bar
13	Open V12 slowly	Supply Lines and disc circuits fill with air. Open slowly to not damage flow meters by large reverse flow.
14	Close any of V4, V5, V6, V7 that were open	Isolate Supply Lines from Disc and Cylinder Boxes, to reduce risk of damage to Supply Lines
15	Close any valves inside Disc or Cylinder Box to circuits	Protect lines inside Boxes

Final State: The disc circuits and supply lines are full of air at atmospheric pressure. The C3F8 is contained in the C3F8 plant. Connections to the disc can be opened, e.g. for disc removal.

6 Operation 6: Final Removal of C3F8

Needed for C3F8 Plant maintenance, or at end-of-life. Aim is to recover C3F8 clean and ready for re-use; and to minimise atmospheric pollution (C3F8 is a powerful greenhouse gas).

These instructions are now obsolete because we have bought a special refrigerant recovery plant. Follow the plant instructions instead of the following. However, the following is left in place until we have worked out just how to use the new recovery unit.

This procedure requires a C3F8 bottle, either with some C3F8 in or evacuated (no moisture!), and with a valve and pressure gauge. This container has to be cooled e.g. by placing in a chiller and cooling to as low a temperature as reachable (but not below -40 °C).

6.1 Operation 6.1: Removal of most of the C3F8

Initial state: Compressor off, liquid pump off, vacuum pump off; All valves closed. C3F8 is in C3F8 Plant following operation 5, but OMITTING step 12 so no air is allowed into the lines. Then Supply Lines are at vacuum with residual C3F8 at 1 mbar.

Step	Action	Result/Comments
1	Carry out Operation 5 (Evacuating C3F8 to Plant and Preparing For Disc Removal) but OMITTING step 12, and check all valves are closed	Initial state check
2	Slowly open V2	Prepare for venting through V3; open slowly to protect flow meter
3	Open SV valve in C3F8 Plant	By-pass the liquid pump
4	Connect the C3F8 bottle to the vent line at V3; open bottle's valve	Bottle ready to receive C3F8
5	Open valve V3	If bottle was at vacuum, some C3F8 gas flows in; otherwise pressures in C3F8 Plant and bottle equalize
6	Start cooling the bottle	C3F8 condenses in bottle, pressure reduces in C3F8 plant, C3F8 evaporates in plant
7	Wait until C3F8 in plant is at room temperature and it's pressure is appropriate to the bottle temperature	All C3F8 liquid in C3F8 Plant has evaporated
8	Close V3 and the valve on the bottle, and disconnect the bottle	Most of the C3F8 is now in the bottle

Final state: Most of the C3F8 is in the bottle, and being kept cold by a chiller. The C3F8 Plant and some of the Supply Lines contain C3F8 gas at a pressure corresponding to the temperature achieved in the bottle; this may be upto 3 bar. Ready for final C3F8 Recuperation.

6.2 Operation 6.2: Recuperation of residual C3F8 gas

This is only possible if the bottle can be cooled so that the C3F8 pressure in it is below the maximum pressure that the vacuum pump can handle. If not, either the residual C3F8 has to be vented to air or a second pump stage has to be attached to V12 so that the outlet pressure of the vacuum pump is low enough.

Initial state: after Operation 6.1, i.e. compressor off, liquid pump off, vacuum pump off; SV (the liquid pump by-pass) and V2 open; all other valves closed. C3F8 bottle cold and pressure below 2 bar absolute (maximum outlet pressure of vacuum pump).

Step	Action	Result/Comments
1	Check inital state	Safety and avoid escape of C3F8 from bottle to Plant
2	Read instruction 11 and take appropriate action	Decide if you want to also recover C3F8 from flowmeters
3	Close V2	Protect flow-meter against reverse flow
4	Connect C3F8 bottle to V12 vent and open bottle valve	Bottle ready to receive more C3F8
5	Open V10	C3F8 will flow opposite direction to normal through V10
6	Check Pvac is safe for vacuum pump; open V9	Vacuum inlet prepared
7	Check bottle pressure is low enough for vacuum outlet; open V12	Vacuum outlet prepared
8	Turn vacuum pump on	Residual C3F8 is pumped to the bottle
9	Wait till Pvac stops decreasing	Maximum vacuum achieved
10	Close bottle valve, V9 and V12; turn off vacuum pump	As much C3F8 as possible is in the bottle
11	Turn off bottle chiller	Bottle is ready for removal and storage
12	Open V3	Vent small quantity of C3F8 from mass flow meters. Alternatively this volume could also be return to the bottle via the Disc-Box evaporator by opening V4 and V6 before step 5.
12	Set nitrogen regulator to just above 1 bar absolute; open V8 until circuit is just above atmospheric pressure; close V8	C3F8 Plant is full of nitrogen (to avoid moisture in it)
13	Slowly open V2	Adjust nitrogen pressure to atmospheric
14	Close V10 and V2	C3F8 Plant is isolated and full of nitrogen at atmospheric pressure, ready for maintenance/storage
15	Open V4, V5, V6, V7	All lines brought to atmospheric pressure with air

Final state: As much C3F8 as possible is recovered into the bottle; small amount vented to atmosphere; C3F8 plant full of nitrogen at atmospheric pressure; lines open to air. Plant can be maintained or stored; bottle can be stored or returned to supplier.