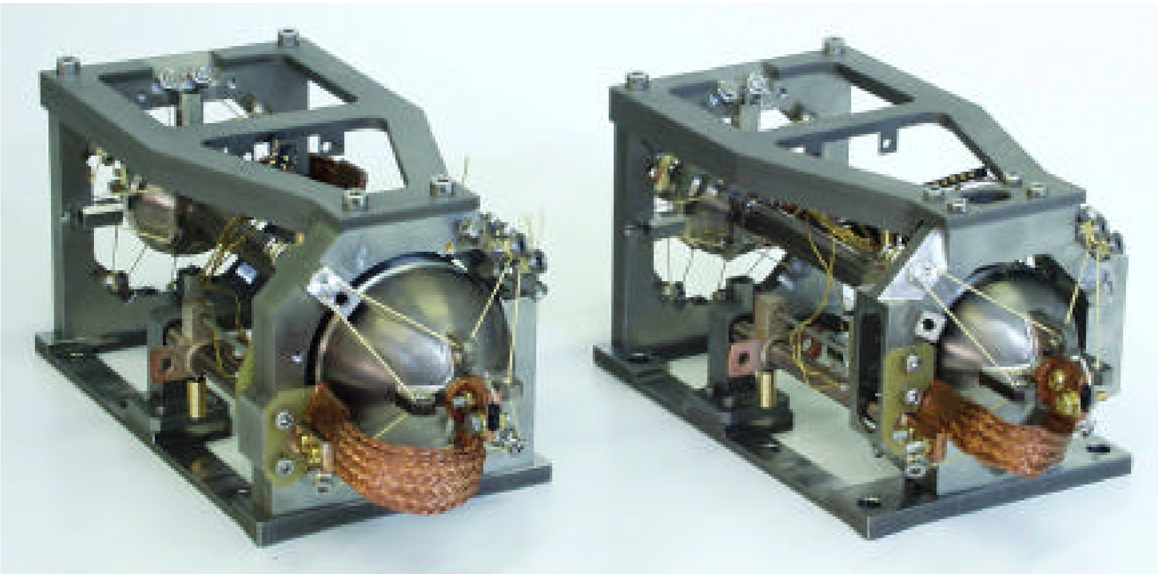
SERVICE DES BASSES TEMPERATURES

CRYOGENIC SORPTION COOLER

ESA Contract # 12942/98/NL/PA



DRIVE ELECTRONIC PRELIMINARY DEFINITION

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DRIVE ELECTRONIC PRELIMINARY DEFINITION

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EUROPEAN SPACE AGENCY CONTRACT REPORT
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CONTENTS

1 Introduction

This note contains a preliminary description of the drive (and control) electronic for both sorption coolers, ^{3}He and ^{4}He. The overall principle, the functions required and an algorithm are discussed.

However this note does not contain circuit board schematics or any hardware drawings. Its content is intended to provide guidelines for future electronic definitions. In particular the control electronic of the SPIRE cooler will eventually have to be architectured using these guidelines and manufactured by identified subcontractors. For SPIRE it is not foreseen to have a dedicated electronic for the cooler but rather to implement these functions in the master electronic.

For the present ESA contract a laboratory electronic will be used in the form of a commercial temperature controler driven by a desktop computer. Nevertheless keeping in mind future development we have initiated a first draft definition of the control electronic.

This electronic shall permit to address the following functions :

- full recycling of the cooler
- check of proper operation - help in the diagnostis of potential problems
- control of the evaporator (detector) temperature at a desired value to better than TBD

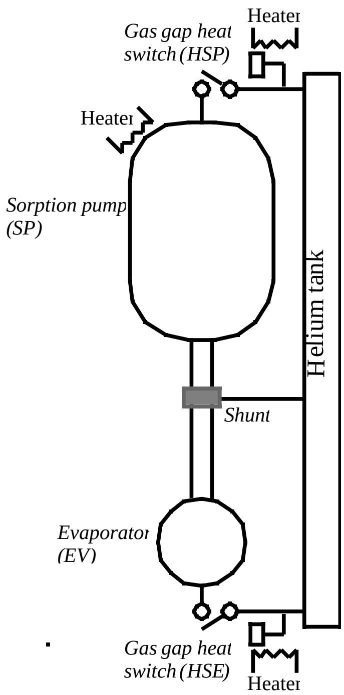
2 Review of principle of operation

The detail of the complete thermodynamical operation of an helium sorption cooler can be found in the technical note "*Description of design tools and results of preliminary analysis*" – reference TN/SBT/SC/99-01. We summarize hereafter this operation from a thermal point of view.

2.1 Basic thermal operation of the cooler

The figure hereafter shows a schematic of a sorption cooler. This schematic applies to both ^{3}He and ^{4}He coolers. Whenever relevant the differences in the sequence of operation for both cooler are indicated.

The cooler is basically made of four components designated as a sorption pump SP, an evaporator EV, two gas gap heat switches HSP and HSE respectively connected to the sorption pump (SP) and evaporator (EV). A typical recycling begins when all these components are at a temperature below 3 K for ^{3}He cooler, or 5 K for ^{4}He cooler – at this temperature both heat switches HSP and HSE are OFF, and all of the helium gaz is stored in the sorption pump. The sequence of operation is then :



(a) :
power is applied to HSE to turn it ON (HSP is OFF)

(b) :
power is applied to SP until SP reaches 40 K (^{3}He) or 50 K (^{4}He)

(c) :
when SP reaches 40 K (or 50 K) power is reduced to maintain this temperature for 10 minutes (this delay can be shorten)

(d) :
power on SP is then turned OFF

(e) :
power on HSE is turned OFF to switch to OFF position

(f) :
power is applied to HSP to turn it ON

The timing of these various phases can vary; for instance depending on the thermal time constant of the heat switches, in particular on the difference between the ON to OFF and OFF to ON times, a delay could be needed between phase (e) and (f), or (e) and (f) may be switched. This timing depends on the particular specifications established for the heat switches, the peak power allowed during recycling, etc…

Following this sequence of actions the cooler reaches its ultimate temperature (low temperature phase) and remains there until all the liquid helium is exhausted. During this phase, basic operation of the cooler (no regulation – see further) only requires to keep HSP ON.

2.2 Advance operation of the cooler

Experience have demonstrated that at least two additional features could be required for the operation of the cooler :

- temperature regulation of the evaporator
- adjustment of hold time (partial recycling)

2.2.1 Temperature regulation

The reader is referred to the technical note "*Description of design tools and results of preliminary analysis*" – reference TN/SBT/SC/99-01 for further detail. The basic principle to achieve this control is to adjust the pumping speed of the sorption pump (SP) via a regulation of its temperature. This concept has been extensively tested in the laboratory over a wide range of set points, and has provided excellent results. However some important remarks must be made and understood.

- if the desired evaporator temperature is significantly above the "natural" ultimate temperature (unregulated), a degraded ON position for HSP is required (to limit the power dumped onto the helium tank)
- after the cooler has reached its natural ultimate temperature, one can turned OFF HSP resulting in an increase of the pump temperature. Then two scenarios can happen :
    - 1) T_{pump} is such that the evaporator temperature is above the set point. In this case it could be possible to regulate the ON conductance of HSP (by applying power) to lower T_{pump}.
    - 2) T_{pump} is such that the evaporator temperature is below the set point. In this case it could be possible to apply power directly onto the pump to raise its temperature.

    Note that whichever scenario is used, this regulation technique does not impact on the cooler efficiency.

These features must be though implemented in the control electronic, and lead to an increase complexity.

2.2.2 Hold time control

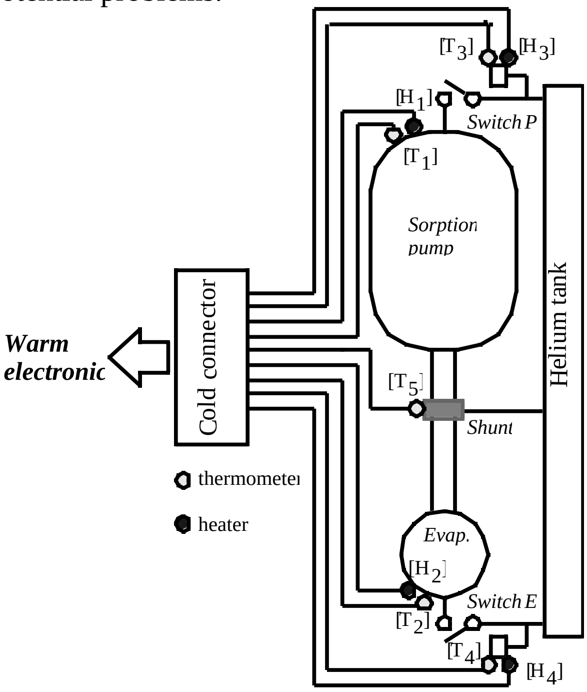
It is possible to fully adapt the hold time of the cooler. In general a nominal hold time has been specified leading to a sizing for the sorption cooler. However it could be interesting to keep some flexibility (failure of one set of detectors, modification of observing strategy, etc…). Indeed in this case the efficiency of the cooler (power dissipated onto the helium tank) could be optimised.

The only efficient way to control this hold time is by varying the sorption pump temperature during recycling, ie varying the amount of power applied to it. For a given cooler a map of hold times versus pump and heat sink temperatures can be produced, and possibly be available through the control electronic.

Obviously all these features increase the complexity of the drive electronic, and the user must define upstream which of them are required.

3 Instrumentation

On the following schematic we have reported the various thermometers and heaters required for the cooler operation - not all of them are absolutely necessary as shown in the following table, however this configuration allows for a better control of the operation and ease the diagnosis for potential problems.



Reference	Item	Range	Accuracy & Resolution	No of wires	Status
	minimum set appears in gray				
T_1	Sorption pump temperature	1.5 K – 50 K	A ≤ 1 K R ≤ 0.5 K	4	Required
H_1	Sorption pump heater	0 – 500 mW		2	Required
T_2	Evaporator thermometer	0.25 – 10 K	A ≤ 5 mK R ≤ 0.1 mK	4	Required
H_2	Evaporator heater	0 – 1 mW (^{3}He) 0 – 10 mW (^{4}He)		2	Optional
T_3	Miniature sorption pump thermometer on sorption pump heat switch	1.5 – 25 K	A ≤ 1 K R ≤ 0.5 K	4	Required
H_3	Miniature sorption pump heater on sorption pump heat switch	0 – 1 mW		2	Required
T_4	Miniature sorption pump thermometer on evaporator heat switch	1.5 – 25 K	A ≤ 1 K R ≤ 1 K	4	Required
H_4	Miniature sorption pump heater on evaporator heat switch	0 – 1 mW		2	Required
T_5	Thermometer on thermal shunt	1.5 – 10 K	A ≤ 0.1 K R ≤ 0.1 K	4	Optional

In addition we have indicated in the above table the absolute minimum components required for operation of the cooler (gray cells in the table), assuming the cooler is operating to nominal and all the thermal conductances have been previously characterized; this means for instance that once the temperature response of the sorption pump as a function of the

applied power is known, the thermometer on this pump is not required anymore. It is pointed out that this does not mean that this thermometer is not required in the first place but that in case of failures the cooler can still be operated with this minimum set of items. This concept must be kept in mind because the drive electronic will operate following a defined algorithm, where a number of conditions must be fullfilled before the cooler can actually be recycled and then can reach its operating temperature. It could be interesting then to implement an “emergency recycling“ (or blind operation) where the recycling process is effected without any information on the various temperatures.
A fully instrumented cooler requires 28 wires – in general thermometers and heaters are doubled for redundancy purpose leading to a grand total of 56 wires. If the optional items are removed this number becomes 44. Note also that to further increase reliability the heaters can wired with 4 wires.

4 Cooler states

The cooler can be in various states as described hereafter :

- *state 0* : cooler is at ambiant temperature (300 K) – this state is only pertinent during ground tests - no functions possible. Note that the gas gap heat switches are in the ON position (OFF position requires temperature below 10 K).

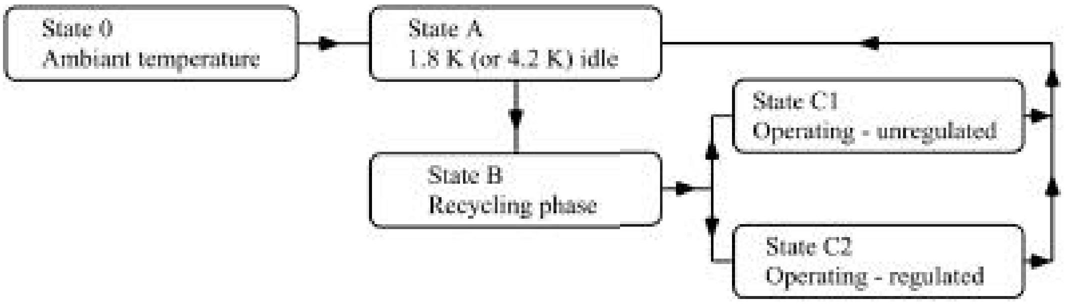
- *state A* : 1.8 K idle (or 4.2 K for the ^{4}He cooler). The cooler is in standby mode, ready for recycling. All switches are in the OFF position. No power is dissipated by the cooler neither any current or voltage are required.

- *state B* : Recycling. This is the most complex state of the cooler; it comprises sequences of heating and cooling as described in the following paragraph

- *state C* : Operating. This state corresponds to the low temperature phase when the cooler is operating at sub Kelvin temperature. Two sub state can be defined :

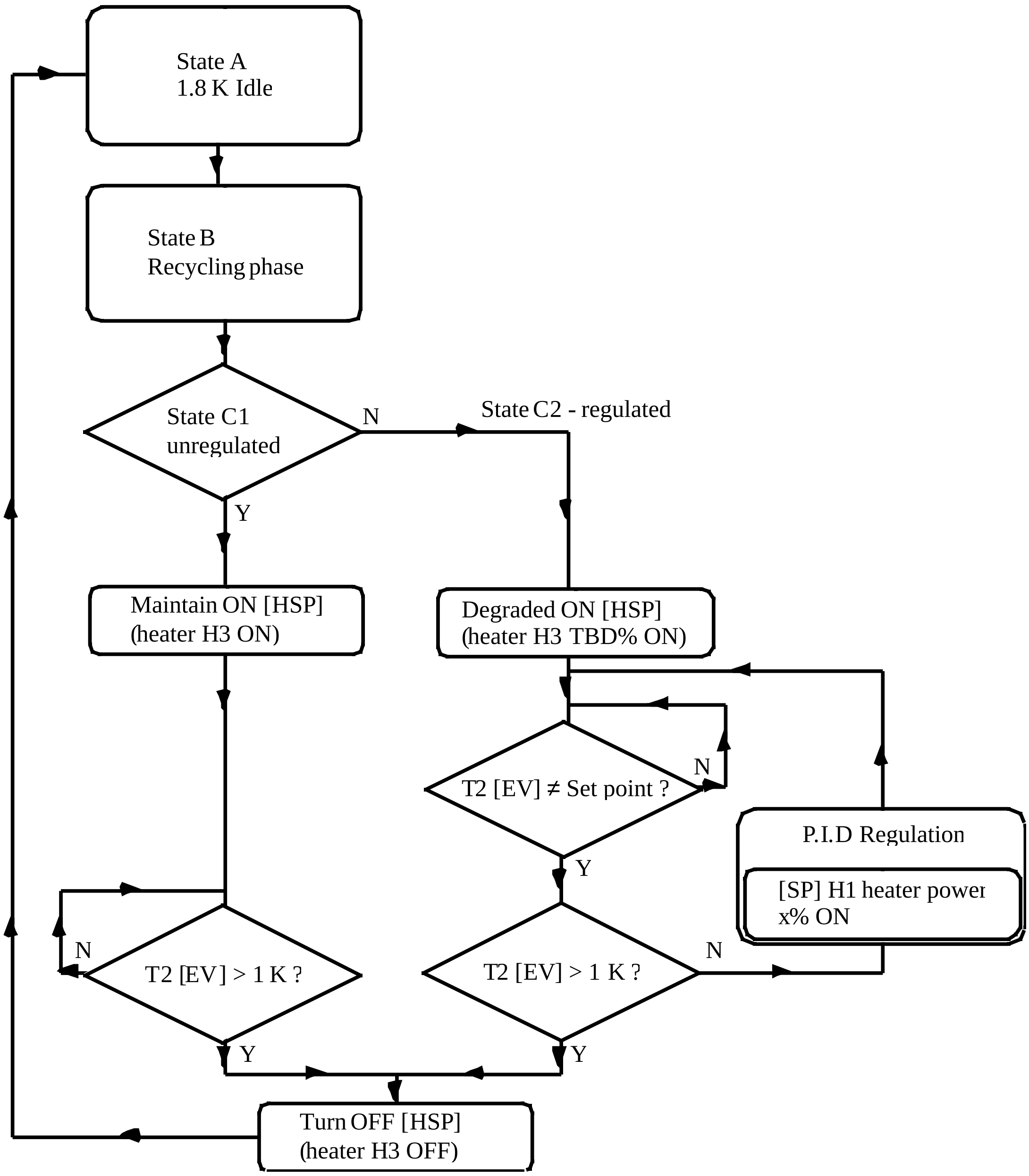
    - *state C1* : unregulated – No active control of the operating temperature is performed and the ultimate temperature is a function of the thermal environment (load, parasitics, etc…)
    - *state C2* : regulated – The evaporator is regulated at some desired temperature. This temperature regulation is achieved by adjusting the pumping speed of the sorption pump via a regulation of its temperature (see “*Description of design tools and results of preliminary analysis*” – reference TN/SBT/SC/99-01).

The schematic hereafter summarizes these states and their links.



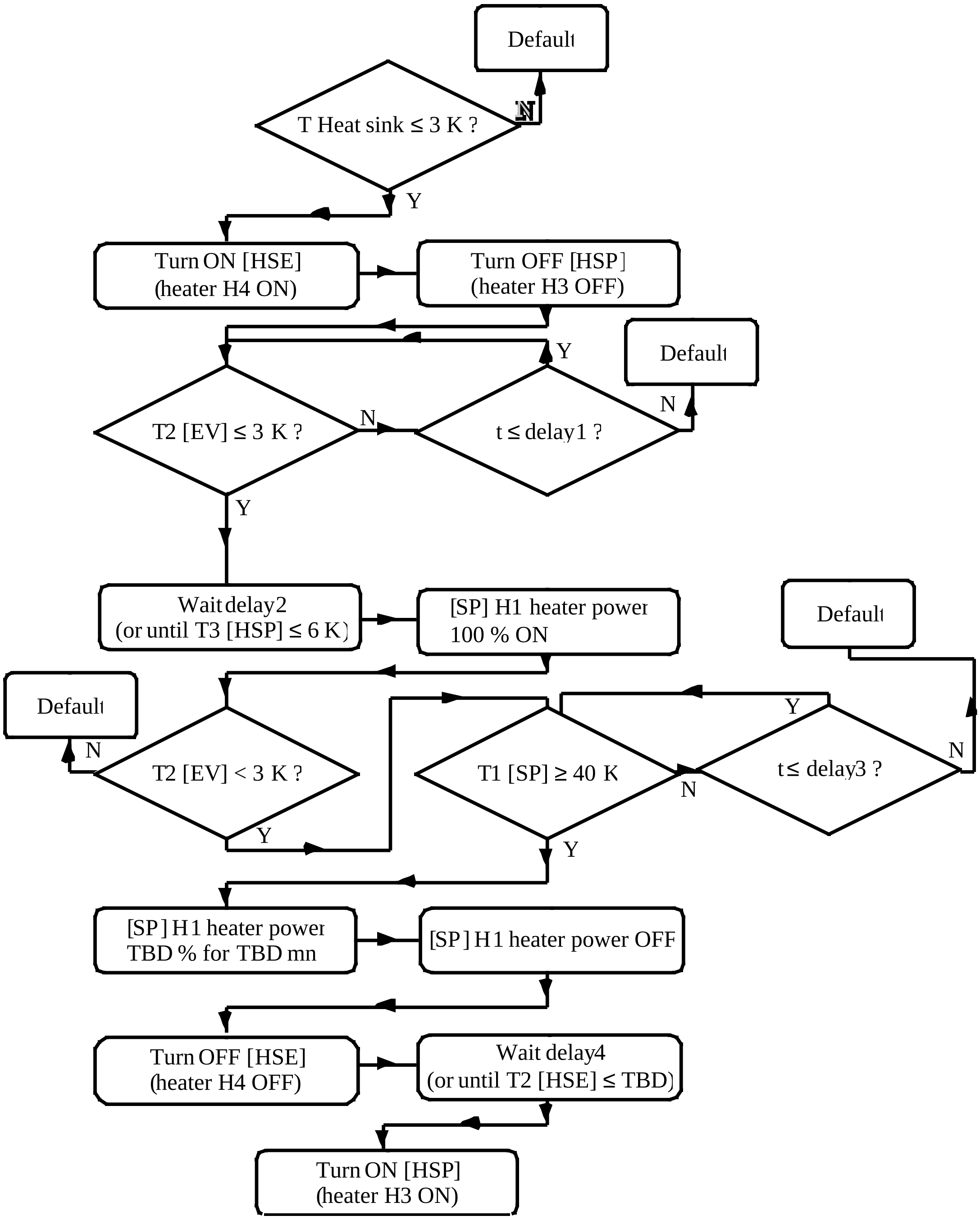
5 Control algorithms

A general algorithm for the operation of a ^{3}He cooler is shown below. The algorithm for the ^{4}He cooler is similar, only the temperature characteristics must be changed.
In this algorithm it is assumed the temperature regulation will be effected by adjusting the temperature of the sorption pump (pumping speed).

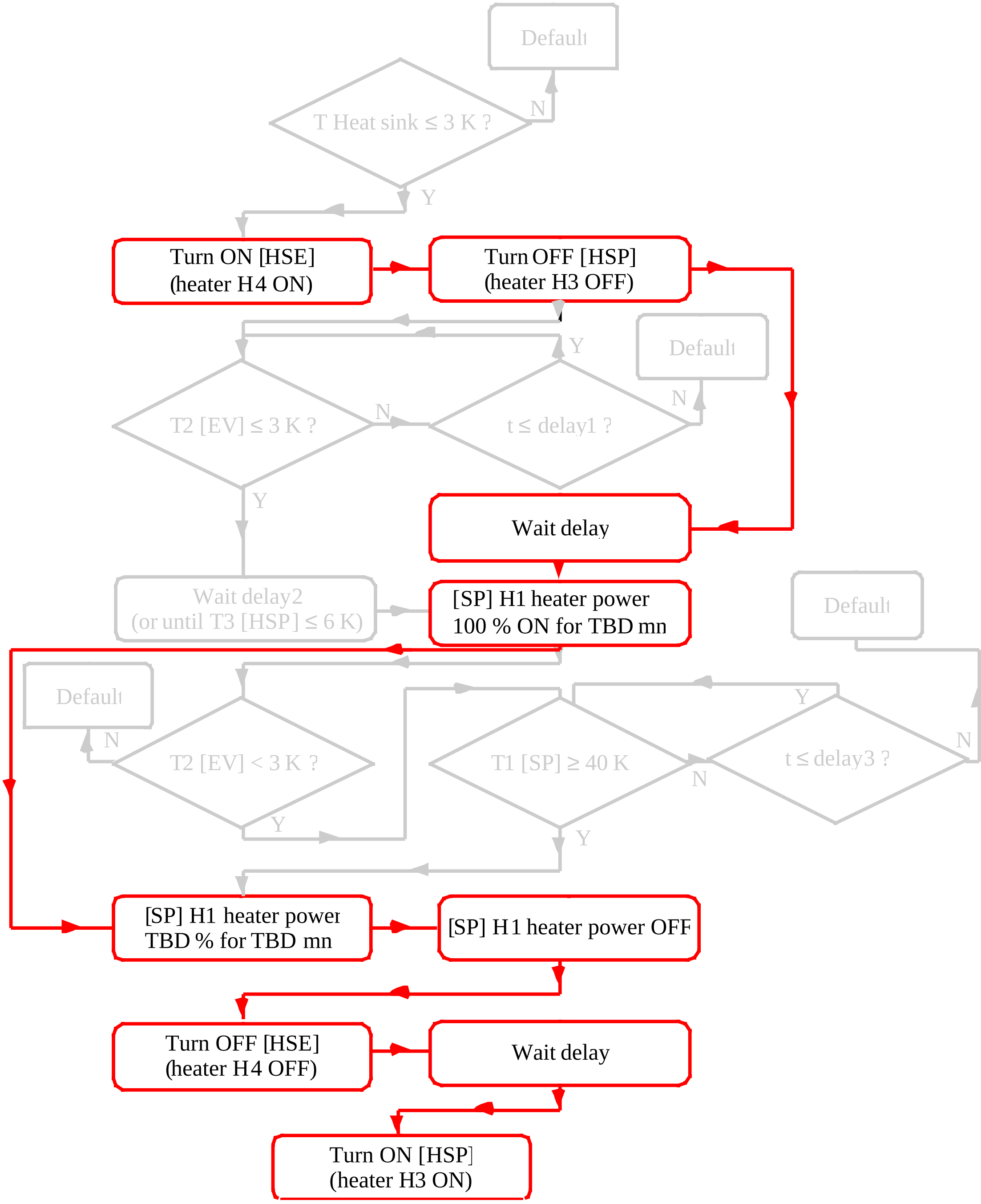


General algorithm

Two algorithms for state B (see § 4) are reported hereafter for the ^{3}He sorption cooler. The first one is associated with a standard cooler recycling, as the second one corresponds to the “emergency recycling” as described in § 3.



State B -Standard recycling



State B - Emergency recycling

After recycling the cooler is in state C. State C1 (unregulated) does not required any specific control besides maintaining ON [HSP] (ie supplying current to H_3) as State C2 (regulated) requires a specific control loop with a PID regulation as shown on the general algorithm.