Gembloux Agro-Bio Tech
Université de Liège

MANAGEMENT OF FORESTRY RESOURCES

CONFIDENTIAL

Validation of the Dryer One process for heat treatment against harmful organisms applied to wood chips intended for export

Professor Jacques HEBERT, Dr Benoit JOUREZ & Ir Jean-Marc HENIN

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DEPARTMENT FOR THE STUDY OF THE NATURAL AND AGRICULTURAL ENVIRONMENT WOOD TECHNOLOGY LABORATORY

Wallonie

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1 INTRODUCTION

1.1 Subject

The Technic One SA company has developed an oven for phytosanitary treatment applied to wood chips with the goal of destroying any organism which could grow in it and then infest forests after having been transported to a region where this organism is initially absent. The treatment is intended to respond to the requirements of standards and health authorities who regulate the international trade of wood based products. In this context, the heat treatment developed must allow wood chips to be maintained at a core temperature of at least 56°C for at least 30 minutes.

Technic One SA has called upon a scientific team in order to validate the treatment through experiments and to formulate recommendations for upgrading its process to the industrial scale.

1.2 Technic One SA

Technic One has its headquarters at: Z.I. Les Plenesses, 76 at B-4890 Thimister – Belgium. The company, identified by its company number 0424.130.718 is represented by Léon Crosset, Chief Executive. Two members of personnel participated actively in the tests, i.e. Messrs. Damien Collard (Project manager) and Nicolas Crosset (design engineer).

Technic One is a company specialised in the design, development, manufacturing and installation of smart, custom industrial equipment. For more than 30 years, the company has thus developed innovative solutions (development of innovative machines, special equipment, production lines, etc.) in activity sectors as diverse as the textile industry, mining, steel making or the manufacture of civil engineering machinery. An overview of the extent of the developments of Technic One is presented on their webpage http://www.technic- one.com/index.php/fr/produits. More recently, Technic One developed and patented a totally innovative drying technology which allows a large range of forest and agricultural products to be treated and exploited: Dryer One (http://www.dryer-one.com/index.php/fr/). It is by adapting this technology that Technic One wishes to produce equipment and a process which will allow wood chips to be treated industrially.

1.3 Scientific team

The team was composed of:

- Benoit Jourez, Qualified Officer and Professor, Service public de Wallonie (SPW) [Wallonia Public Service] – Belgium
  Direction Générale Opérationnelle "Agriculture, Ressources naturelles et Environnement" (DGO3) [General Operational Directorate for Agriculture, Natural Ressources and the Environment]
  Département de l'Etude du Milieu naturel et agricole (DEMNA) Laboratoire de Technologie du Bois (LTB) [Department for the Study of the natural and agricultural Environment - Wood Technology Laboratory]
- Jacques Hébert, Professor at the University of Liège, Gembloux Agro-Bio Tech – Belgium

The team benefited from the scientific assistance of Mr. Jean-Marc Henin (LTB) and the technical support of Messrs Antoine Porsont, Paul-Henri Naumann and Lahcen Hadiy (ULg).

The team has experience concerning the phytosanitary treatment of wood. Recently, this consortium has performed research on the phytosanitary treatment of wood packaging using microwaves. With several publications in international scientific journals (Henin et al. 2008, 2012 and 2014), this research has allowed the conditions which guarantee that international standards for phytosanitary treatment to be clearly guaranteed (see point 2.1).

The LTB has also performed research dedicated to the phytosanitary treatment of wood by anoxia (de Streel et al., 2016).

In addition, apart from the scientific expertise of the two institutional partners and their complementarity, the LTB has a breeding facility of wood-boring insects (see § 3.4) which supplied the biological material necessary for the validation of the treatment. This insect breeding facility in Gembloux is unique in Belgium.

Finally, it is noted that the subject considered (the phytosanitary treatment of wood chips) is a subject of interest for the European and Mediterranean Plant Protection Organisation (EPPO; see § 2.1) also attested to by the EPPO report (2015) to which Mr Jean-Marc Henin contributed.

1.4 Calendar

Contact between Technic One and the scientific team took place in February 2016 in order to define the experiments meant to validate the treatment. Subsequently, the company finished the modification of its prototype in order to meet the requirements of the standards and international phytosanitary authorities. The experiments were performed in June and July 2016. They were preceded by preparatory work (laboratory testing, preparation of the insect larvae) and followed by the analysis of the results and the writing of the report.

2 CONTEXTUAL ELEMENTS

2.1 Regulatory aspects

The wood coming from dead or living trees can be infested with harmful organisms such as insects, fungi or parasitic worms. When infected wood is exported (in diverse forms: logs, sawdust, chips, packaging material, dunnage, etc.) to a region where the organisms housed within it are naturally absent, the latter can sometimes establish permanent populations there and in certain cases lead to damaging biological invasions. According to the European and Mediterranean Plant Protection Organisation[1], chips constitute a product to which is associated, depending upon their characteristics, a medium to high risk of biological invasion (EPPO, 2015). These invasions, whose rhythm continually increases because of the increase of human transport and commercial activities, can have disastrous ecological, economic and social consequences.

In order to reduce the risk of biological invasions related to wood transport and trade, internationally accepted phytosanitary measures described in various documents such as European directives or international standards (Directive 2000/29/CE, ISPM15[2] – FAO, etc.) must be implemented.

Amongst the phytosanitary measures, the effectiveness of heat treatment (HT) described in ISPM15, is recognised by all the National Plant Protection Organisations adhering to the International Plant Protection Convention (which currently groups together 182 countries). The heat treatment defined in ISPM15 consists in heating the material so as to guarantee that a minimum temperature of 56°C has been attained in the core of the wood for at least 30 minutes. While originally intended for wood packaging material (pallets, crates, dunnage, etc.), the heat treatment defined in ISPM15 could be considered for wood in other forms (logs, chips, etc.).

More specifically, concerning chips and despite some uncertainties concerning the phytosanitary treatment required for eliminating the complete spectrum of harmful organisms which they could potentially transport (insects, fungi, pathogens, bacteria, viruses, parasitic worms, etc.), heat treatment is a method specifically proposed by the EPPO for the treatment of chips (EPPO, 2015).

2.2 General principles of the treatment process

Since 2013, Technic One has developed and patented an innovative process allowing a large range of forest and agricultural products to be dried. The material to dry is spread over a rotating tray crossed by a hot air flux. After a complete rotation, the partially dried material is transferred to a second rotating tray, where it performs an additional rotation, which finalises the continuous flow drying process.

[1] EPPO (European and Mediterranean Plant Protection Organization). https://www.eppo.int/
[2] ISPM=International Standard of Phytosanitary Measures.

Figure 1 : General operating principle of the dryer.

At this time, Technic One has installed two dryers of this type in Belgium. Since then, the company has turned towards the heat treatment of wood chips for eliminating harmful organisms. It has received a concrete request from a customer in Savannah (Georgia, USA) who wishes to treat wood chips in order to meet the requirements of the phytosanitary standards in force for export.

The drying process developed by Technic One has been modified so as to bring the treated wood chips up to a temperature higher than 56°C at core for at least 30 minutes. By doing this, the process is supposed to guarantee the complete destruction of harmful organisms and the export of the chips could be considered, in compliance with International Standards of Phytosanitary Measures.

It must be experimentally verified however, that obtaining a core temperature of 56°C does not pose a technical problem, whatever the physical characteristics of the chips (temperature and moisture content) which could be encountered in an industrial context. The effectiveness of the treatment must also be checked by a specific experiment using living organisms (insect larvae).

3 DETAILED DESCRIPTION OF THE MODIFIED DRYER

3.1 Treatment process

At the start, the wood chips are laid from a feeder hopper, in a uniform 10 cm thick layer, on a first rotating tray, crossed by a hot air flow whose initial temperature is close to 95°C.

At the end of the rotation on the first disc, i.e. after 10 minutes of exposure to the hot air flow, the wood chips have a core temperature of at least 60°C. When this condition is fulfilled, the chips are transferred to a lower tray rotating three times slower. The chips are laid there in a uniform 30 cm thick layer. The partially cooled hot air flow crosses the lower tray and maintains the wood temperature at 60-65°C during these 30 minutes.

Maintaining at a temperature higher than 56°C during at least 30 minutes allows the naturally high variability of the treated material (in terms of wood density and humidity), to be taken account of and to guarantee the complete elimination of harmful organisms.

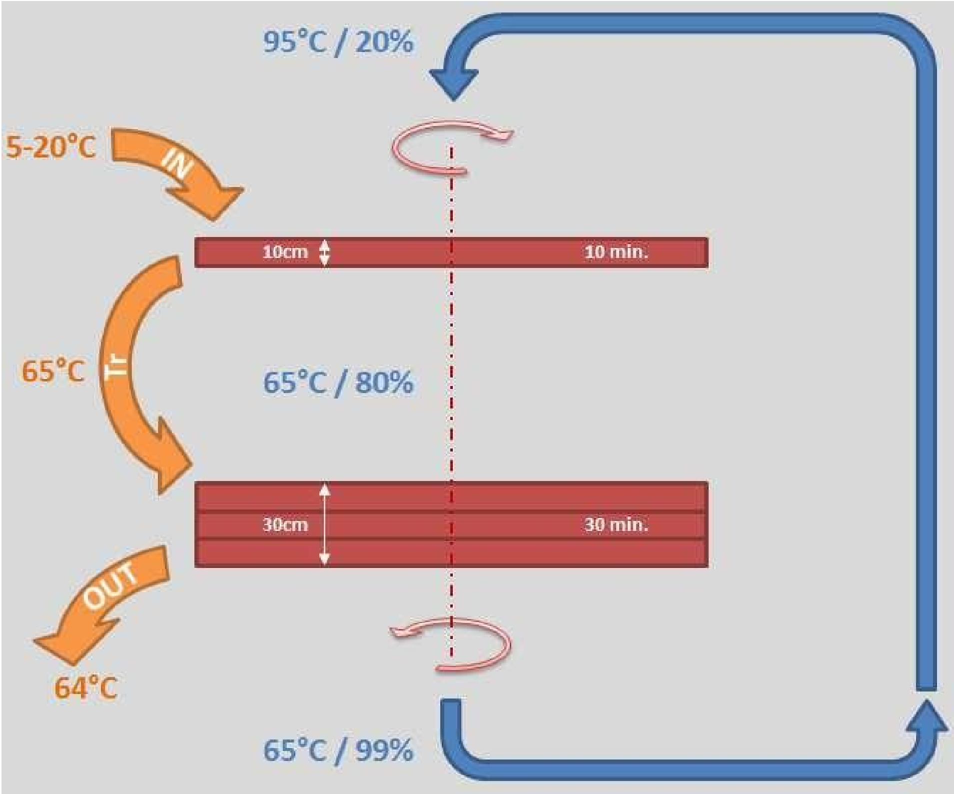


Figure 2 : Operating principle of the modified dryer, with in blue, the air flow, in orange, the transfer of the chips and in red, the chips laid on the rotating discs during their treatment.

In order to optimise the rise and the keeping of the temperature of the raw material, the cooled and humid air is reheated before being re-injected into the oven. In fact, by circulating the air in a closed system, the evaporation of water present in the product to treat is limited.

3.2 Description of the modified dryer

The tests were performed with the prototype of the modified dryer in the workshop of the Technic One company.

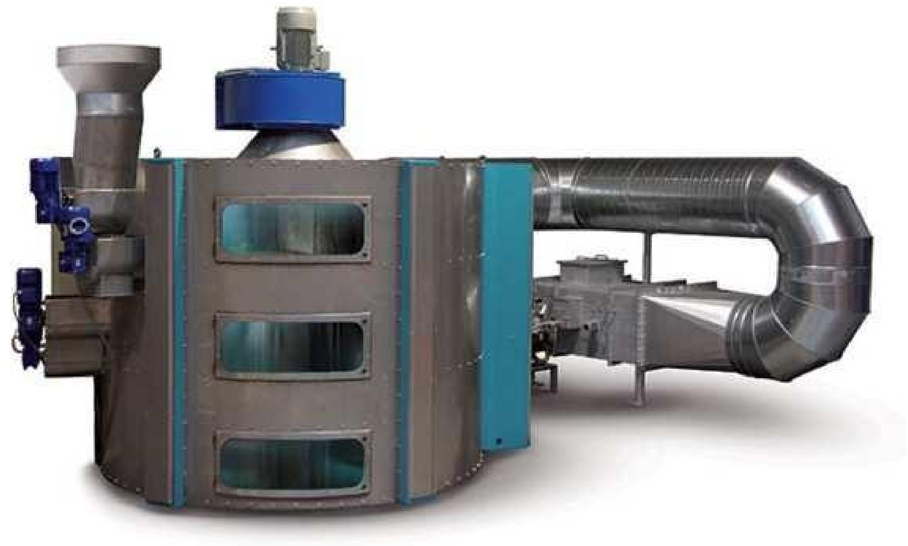


Figure 3 : Overall view of the dryer modified for the treatment of wood chips.

The treatment capacity of the prototype is calculated as follows:

- The useful surface area of a disc is 5.1m². With a 30 cm thick layer of treated wood during 30 minutes, the flow rate is 3.06 m³/h.
- Given that the bulk density of the green wood chips is 385 kg/m³ and supposing an initial moisture content of the wood to be 100% (50% if moisture content is expressed with respect to the total mass), the rate of product treated is 1.1 t/h.

> In this document, the moisture content (mc) is expressed with reference to the anhydrous mass, as follows: mc = (humid mass – anhydrous mass) / anhydrous mass, to be multiplied by 100 to express it in %.
>
> The moisture content with respect to the humid mass (X) is also used in industrial practice. The translation from one to the other is obtained by the relation X = mc/(mc+1).
>
> E.g.: if mc = 135%, than X = 1.35/(1.35+1) = 0.57 = 57%.

The treatment is monitored as follows:

- If the product temperature at the output of the 1st disc (sensor TT60) does not reach at least 60°C, this disc is stopped until the desired temperature is reached.

- If one of the temperature sensors of the 2nd disc (sensors TT70, TT80, TT90) records temperatures less that 60°C, the 2 discs are stopped until all the sensors reach the desired temperature.

- The minimum treatment set-point of the 2nd disc is 30 minutes and this can only be stopped in order to extend the treatment time. The treatment can never be shorter than 30 minutes.

Different infra-red thermometer sensors CT-SF22-C3 of the Micro-Epsilon brand (see sheet in appendix) were distributed in the prototype in order to monitor the product temperature.

- 1 cell at the end of rotation of the 1st disc: Sensor TT60.
- 1 cell at the start of rotation of the 2nd disc: Sensor TT70.
- 1 cell at the middle of rotation of the 2nd disc: Sensor TT80.
- 1 cell at the end of rotation of the 2nd disc: Sensor TT90.

In order to monitor the temperature and humidity of the air, the sensors HC2-IM of the Rotronic brand were placed as follows:

- 1 Sensor at the input to the burner: Sensor TT40.
- 3 sensors distributed at 120° on a plane between the 2 discs: Sensors TT10, TT20 and TT30.
- 1 Sensor at the output of the oven, in the chimney. Sensor TT50.

The air speed in the chimney was measured using a hot wire sensor of type HD2903TC3.5 of the Delta Ohm brand:

- 1 Transmitter at the output of the oven, in the chimney.

In order to check the homogeneity of the temperature of the treated product, a VarioCAM infra-red camera was placed above the conveyor belt, at the output of the oven:

- 1 thermal camera at the product output.

The measurements are recorded by the different probes continuously during each experiment.

3.3 Raw material

The raw material used during the tests was composed of wood in the form of chips having the following characteristics (4 conditionings):

- Type of wood: resinous whose density was determined *a posteriori*
- Dimensions: variable, about 60 x 25 x 6 mm^3
- Moisture content at input: two moisture contents, close to 100% (*green wood*) and 35% (*dry wood*[3], i.e. wood which had lost almost all its free water without drying below the *fibre saturation point - FSP*)
- Input temperature: choice of two temperatures, close to 20°C (ambient temperature) and 5°C (after cooling treatment), to encounter the normal amplitude of annual variations during the implementation of the procedure under operational conditions.

[3] According to international standards (e.g. EN 844-4), wood whose moisture content exceeds ≈30% is labelled "green". However, to make the reading of the present document easier, wood (test specimens and chips) having a mc close to the *Fibre Saturation Point* is here labelled "dry".

3.4 Test specimens with living larvae

The test specimens (wood inoculated with insect larvae) were inserted into the oven through a small trap door at the entrance to the discs, onto the first disc at the same time as the raw material. These test specimens had the following characteristics:

- Wood: Scots pine sapwood;
- Dimensions: parallelepipeds of 15 x 25 x 50 mm³;
- Organism inserted: *Hylotrupes bajulus* larvae;
- Moisture content at input: close to that of the chips;
- Temperature at input: close to that of the chips;

These test specimens were coloured and numbered beforehand in order to easily identify them in the bulk of the chips at the output from the oven. A housing of diameter and depth adapted to the dimensions of the larvae was made on a side face using a drill.

The test specimens were introduced individually amongst the chips at 1 minute intervals during the test cycle, with 22 test specimens per cycle in order to monitor the time of passage in the oven and the homogeneity of the treatment conditions. The larvae introduced into the test specimens belonged to 4 mass categories (1-50 mg; 51-100 mg; 101-150 mg; 151 mg and above). The larvae were extracted from the test specimens in the laboratory the following day in order to check on their state (living, dead or dying).

H. bajulus is a reference species in Europe for the evaluation of the effectiveness of wood phytosanitary treatments (e.g. EN 14128).

In addition, it is important to note that the test specimens containing the larvae were larger than the treated chips. It was more difficult therefore to heat specimens' core up to 60°C. If the larvae introduced were all destroyed by the treatment, *a fortiori*, all those which would have been present in the chips would necessarily be destroyed.

4 EXPERIMENTS

4.1 Blank tests

Blank tests were performed initially with insect free test specimens in order to completely master the operation of the prototype, to check the possibility of finding all the test specimens in the flow of chips at the output, to check the proper operation of the measurement setup and the consistency of the different parameters (humidity and temperature at input and output of the chips, of the air, etc.).

Once the blank tests were finished and conclusive, the actual experiments were performed.

4.2 Experimental tests

Each test was conducted according to the same protocol:

At the start, the oven contained a 10 cm thick layer of chips on the upper disc and a 30 cm thick layer on the lower disc. The role of these chips was to create a situation close to an industrial treatment supposedly operating continuously while the experiment operated in a batch mode.

The larvae came from the *H. bajulus* breeding facility run by the DEMNA. In the days preceding the tests, the larvae lodged in the wood samples placed in an air conditioned chamber were gathered and sorted according to their mass and their vitality was checked; they were then placed individually into small containers.

With regard to the green wood tests, the test specimens were moistened beforehand. An immersion for 40 minutes in distilled water brought the moisture content of the test specimens to about 30 to 50%. An impregnation under vacuum of 15 minutes allowed the moisture content to be brought to about 100 to 120%. On the day of the test, the test specimens were selected according to the desired moisture content (immersion or impregnation) and weighed to check the moisture content. The previously weighed larvae were introduced into the calibrated housings. The housings were plugged with cotton held in by staples. The test specimens were numbered and coloured.

The big bags containing the dry or green chips necessary for a test were brought up close to the prototype. Samples of chips were taken to determine their initial moisture content. In parallel, the temperature of the chips in the core of the big bags was measured using an infra-red probe.

The prototype was then started up. The continuous recording of the operating parameters was started while the fan and the heater were powered up. The rise in temperature of the air was monitored up until the required value. The mobile parts were started up and the chips fed in from the feeder hopper.

The chips intended for the experiment were introduced continuously for about 1h30. This period included the following successive stages:

- Progressive emptying of the upper disc with the test chips from the previous test and filling with the selected chips: 10-15 min
- Continuous filling of chips by pouring from big bags into the feeder hopper and introduction of the test specimens at the input of the upper disc, downstream of the feeder screw, with one test specimens per minute: 22 min
- Continuous feeding of chips by pouring from big bags into the feeder hopper until the exit of the last test specimen: 55-60 min

At the output of the oven, a conveyor belt poured the treated chips into big bags. The test specimens containing larvae were collected on the conveyor belt along with the flow of chips, before falling into the big bag.

During each test and at least 40 minutes after starting the mechanical parts of the prototype (in order to guarantee the elimination of the chips present in the oven during start-up), infra-red photos of the raw material were taken at the output from the oven.

At the end of each test, when the prototype was stopped, the parameters were continuously recorded and the doors were opened to favour the cooling of the installation.

A check of the test specimens was then made and they were weighed before placing them in a vial for later opening in the laboratory in order to examine the status of the larvae.

Finally, a sample of chips was taken from the core of the big bags and weighed in order to determine their residual moisture content after treatment.

4.3 Repetitions

The initial experimental plan called for three repetitions for each combination of moisture content and temperature factors of the chips. The objective was to frame the real operating conditions of the oven. Thus, green or dry chips were treated under summer (20-25°C) and winter (5-10°C) conditions. For the latter, a refrigerated truck was used in order to cool the green chips over two days to bring them to a temperature between 0 and 5°C. The volume of chips thus prepared allowed two tests to be performed. If the physical parameters indicated that the oven could easily bring cooled green chips to the desired temperature meeting the same timing, then tests on cooled and dry chips would be superfluous. In fact the energy needs are higher for cooled, green chips. This point will be discussed later (see 5.4).

4.4 Inspection

For each test, control larvae coming from the same batch were kept under the temperature and moisture content conditions of the chips without passing through the oven. Their state was inspected at the same time as that of the larvae having undergone the heat treatment.

5 RESULTS

5.1 General presentation

The results discussed here do not concern the blank tests whose purpose was to adjust the experiments and to master the operation of the prototype. These tests lasted 3 days.

A laboratory test was performed to measure the heat transfer inside a test specimen (wooded block, 15 x 25 x 50 mm^3), under controlled conditions.

The actual experiments, performed over 5 days, included 8 complete tests, succinctly discussed below in their chronological order.

Test 1: Green chips and ambient temperature (repetition 1, 01/07/2016)

Test 2: Dry chips and ambient temperature (repetition 1, 11/07/2016)

Test 3: Green chips and ambient temperature (repetition 2, 11/07/2016)

Test 4: Dry chips and ambient temperature (repetition 2, 12/07/2016)

Test 5: Dry chips and ambient temperature (repetition 3, 12/07/2016)

Test 6: Green chips and ambient temperature (repetition 3, 13/07/2016)

Test 7: Green chips and cold temperature (repetition 1, 18/07/2016)

Test 8: Green chips and cold temperature (repetition 2, 18/07/2016)

The initial number of tests fixed at 12 was brought to 8 for reasons explained further.

5.2 Rise of the temperature in the test specimens

A laboratory test was performed to measure the time required for a test specimen introduced into a chamber, rapidly heated to 95°C, to reach a core temperature of 56°C. The objective was to ensure that the 10 minutes planned in the industrial process would be sufficient. It should be recalled that the thickness of the test specimens (15 mm) was much greater than that of the chips (5 mm). If the test was satisfactory for the test specimens, *a fortiori*, the objective would be achieved for the chips.

An insulated chamber was heated by high power infra-red lamps lighted at the moment when the test specimen was introduced. A probe measured the air temperature inside the chamber while a pt100 probe was introduced into the core of the test specimen.

The experiment was conducted with dry test specimens (8 to 11%) and other green ones (94 to 130%), prepared at 22°C. The time required to reach 60°C at core (value targeted by the industrial partner to guarantee that the threshold of 56°C was exceeded) varied from 3’56” to 6’40” for the dry test specimens and from 8’25” to 8’42” for the green test specimens.

During the tests with the industrial prototype, the test specimens would be introduced directly into a turbulent air flow at 95°C during 10 minutes. Their internal heating would be even faster than during the preliminary experiment (in the framework of which there was no air turbulence and where the heating of the wood and the air was simultaneous, induced by the heating by the lamps). In conclusion, the internal temperature of 60°C will likely be largely exceeded in the test specimens and therefore in the chips, three times thinner.

5.3 Analysis of the treatment tests for chips at ambient temperature

The initial temperature of the chips varied from 17 to 23°C during the different tests.

Moisture content of the test specimens

	Repetition (test)	Before treatment	After treatment
Green test specimens	1 (1) 2 (3) 3 (6)	145% 125% 131%	110% 111% 79%
Average		134%	100%
Dry test specimens	1 (2) 2 (4) 3 (5)	47% 38% 37%	20% 15% 13%
Average		41%	16%

Moisture content of the chips

	Repetition (test)	Before treatment	After treatment
Green chips	1 (1) 2 (3) 3 (6)	96% 123% 119%	62% 27% 42%
Average		112%	44%
Dry chips	1 (2) 2 (4) 3 (5)	49% 31% 23%	22% 7% 3%
Average		34%	11%

Number of *H. bajulus* larvae by mass category

	Repetition (test)	1-50 mg	51-100 mg	101-150 mg	> 151 mg	Total
Green test specimens	1 (1) 2 (3) 3 (6)	4 1 1	8 11 11	2 2 2	8 8 8	22 22 22
Dry test specimens	1 (2) 2 (4) 3 (5)	1 1 2	11 11 10	2 2 2	8 8 8	22 22 22

In tests as per European standards for the evaluation of the effectiveness of biocide treatments, in principle, larvae weighing from 50 to 150 mg are used. It was demonstrated however, in our tests of phytosanitary treatment by microwaves (Henin et al., 2014), that the largest larvae were more resistant to the thermal treatment. From now on it seems pertinent to evaluate the effectiveness of the treatment on larvae of more than 150 mg.

Mass of *H. bajulus* larvae (in mg)

	Average	Standard deviation	Minimum	Maximum
Test 1	163	131	41	446
Test 3	190	157	46	598
Test 6	188	150	47	526
Test 2	189	150	47	526
Test 4	187	147	50	493
Test 5	186	147	50	489

Results of temperature measurements

The temperatures measured by the different probes were continuously recorded. This allows an overall vision to be had throughout the treatment and to check that the temperature at different locations in the oven was always higher than 56°C.

The overall diagram of the system is shown below:

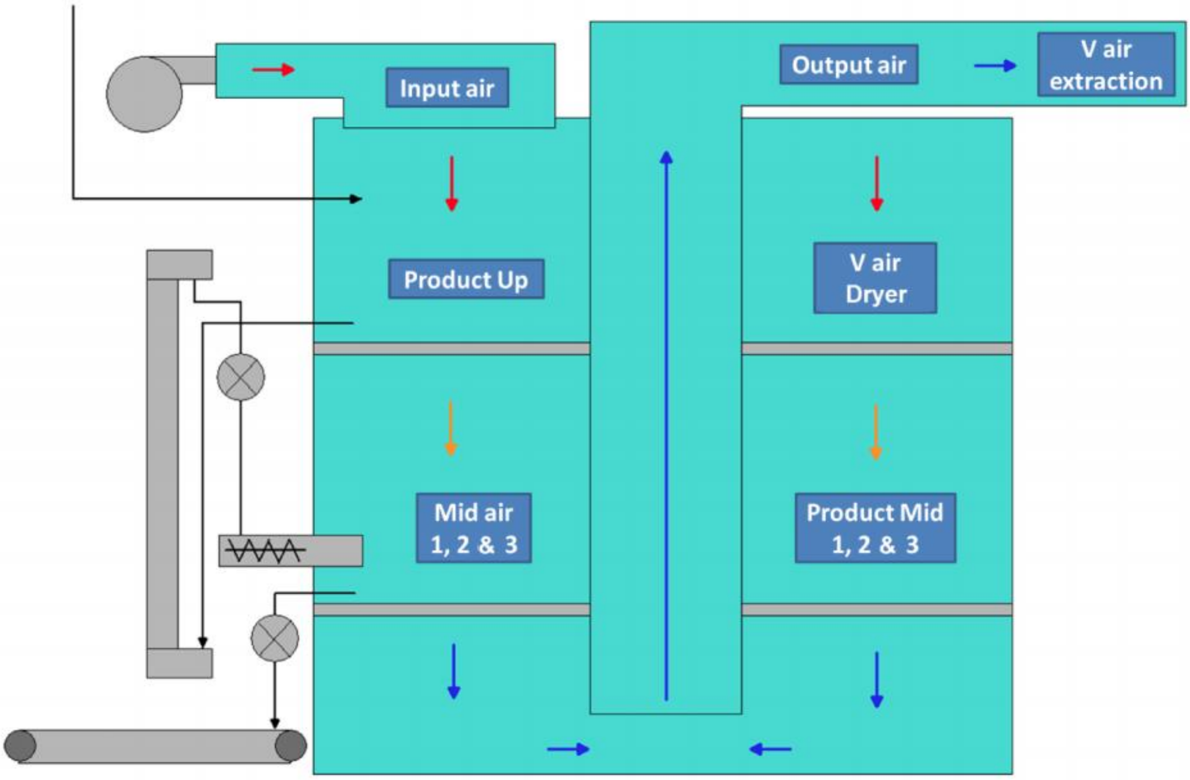


Figure 4 : Cross section diagram illustrating the circulation of input air (red arrows), progressively cooled during the treatment of the chips (orange arrows, then blue arrows). The zones where the sensors were placed are also shown (blue frames).

The location of the sensors described below is specified in figures 4, 5 and 6.

- Product up: temperature (°C) of the chips at mid-thickness of the 10 cm layer, after 10 minutes of treatment by hot input air, just before their transfer from the upper disc to the lower disc (sensor TT60).

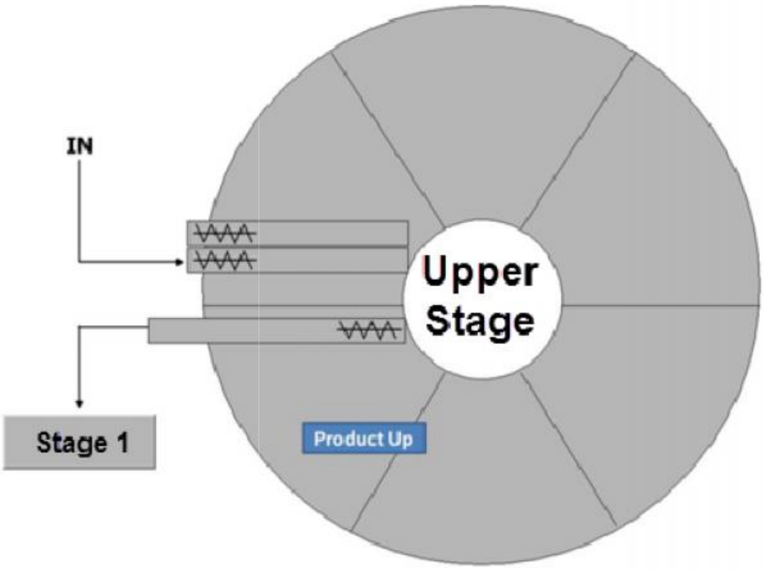


Figure 5 : Top view of upper disc indicating the movements of the chips and the zones where the sensors were placed.

- Product Mid 1: temperature (°C) of the chips at the surface of the 30 cm layer, just after their transfer onto the lower disc (sensor TT70).

- Product Mid 2: temperature (°C) of the chips at the surface of the 30 cm layer, 15 minutes after their arrival onto the lower disc (sensor TT80).

- Product Mid 3: temperature (°C) of the chips at the surface of the 30 cm layer, 30 minutes after their arrival onto the lower disc, just before their output to the exterior (sensor TT90).

- Input air: temperature (°C) of hot air brought to a temperature close to 95-100°C by the heater, at its entrance into the summit of the prototype (sensor TT40). To recall, the hot air was sucked through the upper disc (it cooled and loaded up with humidity). It was then sucked through the lower disc before returning to the heater through a wide central chimney.

- Mid Air 1: temperature (°C) of the air in the zone situated between the two discs, the sensor being situated in the immediate neighbourhood of the product sensor TT70 (sensor TT70).
- Mid Air 2: temperature (°C) of the air in the zone situated between the two discs, the sensor being situated in the immediate neighbourhood of the product sensor TT80 (sensor TT80).
- Mid Air 3: temperature (°C) of the air in the zone situated between the two discs, the sensor being situated in the immediate neighbourhood of the product sensor TT90 (sensor TT90).

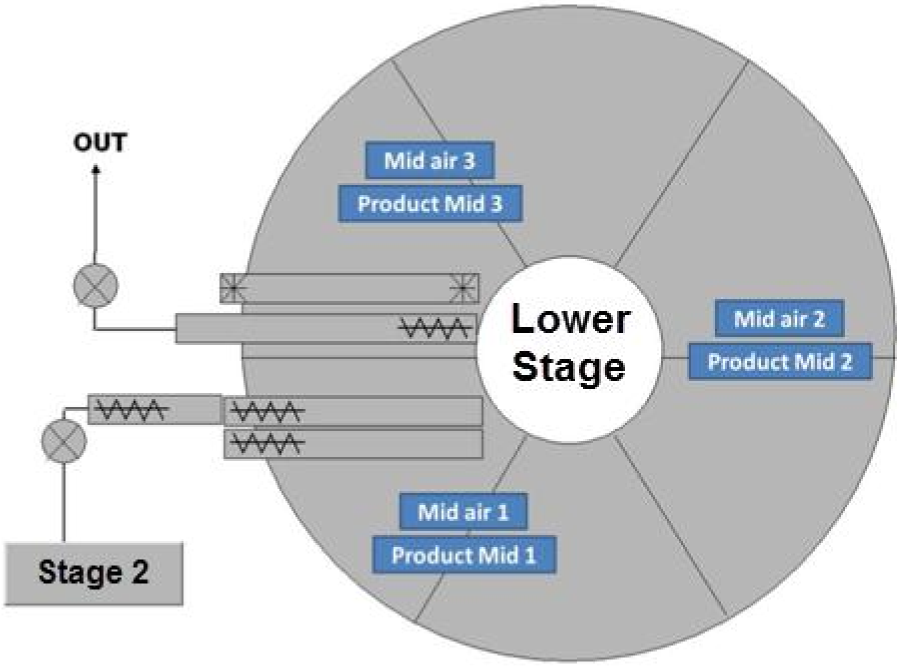


Figure 6 : Top view of lower disc indicating the movements of the chips and the zones where the sensors were placed.

The analysis of the results focuses firstly on the most frequent situation: The treatment of green chips (moisture content close to 100%) in temperate conditions (20°C).

Three tests were performed on green chips at ambient temperature. The characteristics of the chips were summarized above. The three graphs (Fig. 7, 8 & 9) show the evolution of the temperature of the chips throughout the period which covers the treatment of test specimens containing larvae. This period was followed by 40 minutes of treatment during which the chips present during the installation at the start of the test were progressively eliminated and replaced by the chips which were experimented on.

The temperature curves relative to air could be easily identified: logically, they fluctuated less than the temperature of the chips.

Test on green chips at ambient temperature (tests 1, 3 and 6)

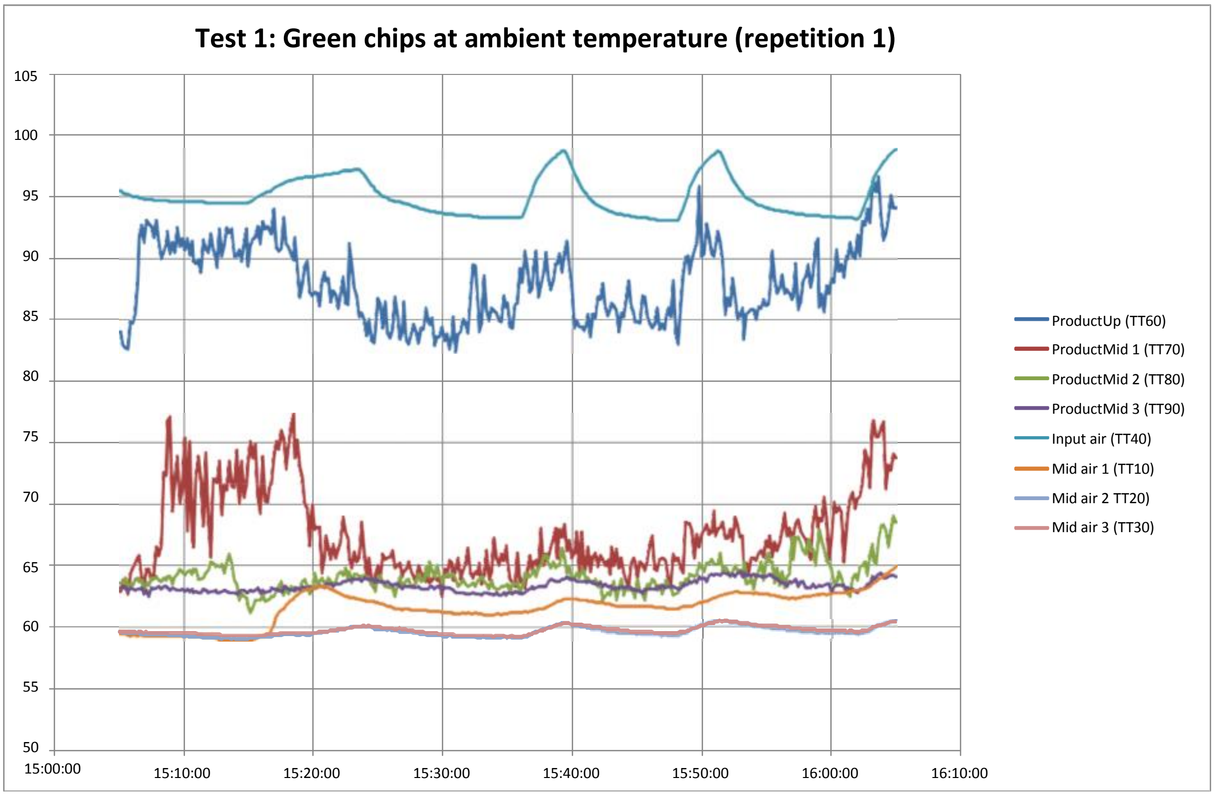


Figure 7: Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 1 July 2016 during the residence period of the larvae in the oven.

It can be seen on Fig. 7 that the input air is maintained at a temperature close to 95°C. The temperature of the chips after 10 minutes varies from 85 to 90°C for those situated at the centre of the 10 cm thick layer. The chips cooled down during their transfer (not optimised on the prototype) towards the lower disc. Their temperature upon arrival on the lower disc was between 65 and 75°C.

After passing through the 10 cm layer, the air lost a part of its energy and cooled. It stayed at between 60 and 65°C. The chips cooled slightly and more slowly due to their thermal inertia. Their temperature stayed around 63°C during 30 minutes. The requirements of ISPM15 standard (i.e. to maintain at least 56°C at core during at least 30 minutes) were therefore met. It is considered that the difference in temperature between the surface and the core of the chips was negligible given the treatment time at 95°C and especially with the smaller thickness of the chips. In addition, all the larvae were killed by the treatment, while the thickness of the test specimens and their moisture content were higher than those of the chips.

The following two repetitions confirmed these observations. It was noted that the preparation of the chips was a difficult stage. In fact, it was difficult to ensure homogeneity of the moisture content of the chips which had to be re-humidified by adding liquid water.

The increase of the temperature observed between 15h20 and 15h30 on Fig. 8 was probably due to the treatment of chips with lower moisture content. Nevertheless, the minimum temperature of the chips stayed at around 62-63°C during tests 3 and 6 (Fig. 8 & 9).

During test 6, the settings were modified, causing a greater fluctuation of the input air temperature, as well as a higher variability of the temperature of the chips upon their arrival onto the lower disc. These fluctuations damped out perfectly during the 30 minutes of maintaining the temperature above 60°C.

It should be noted that no larva survived during tests 1, 3 and 6. It can be concluded therefore, that the process allows green chips at ambient temperature to be effectively treated and the requirements of ISPM15 to be met.

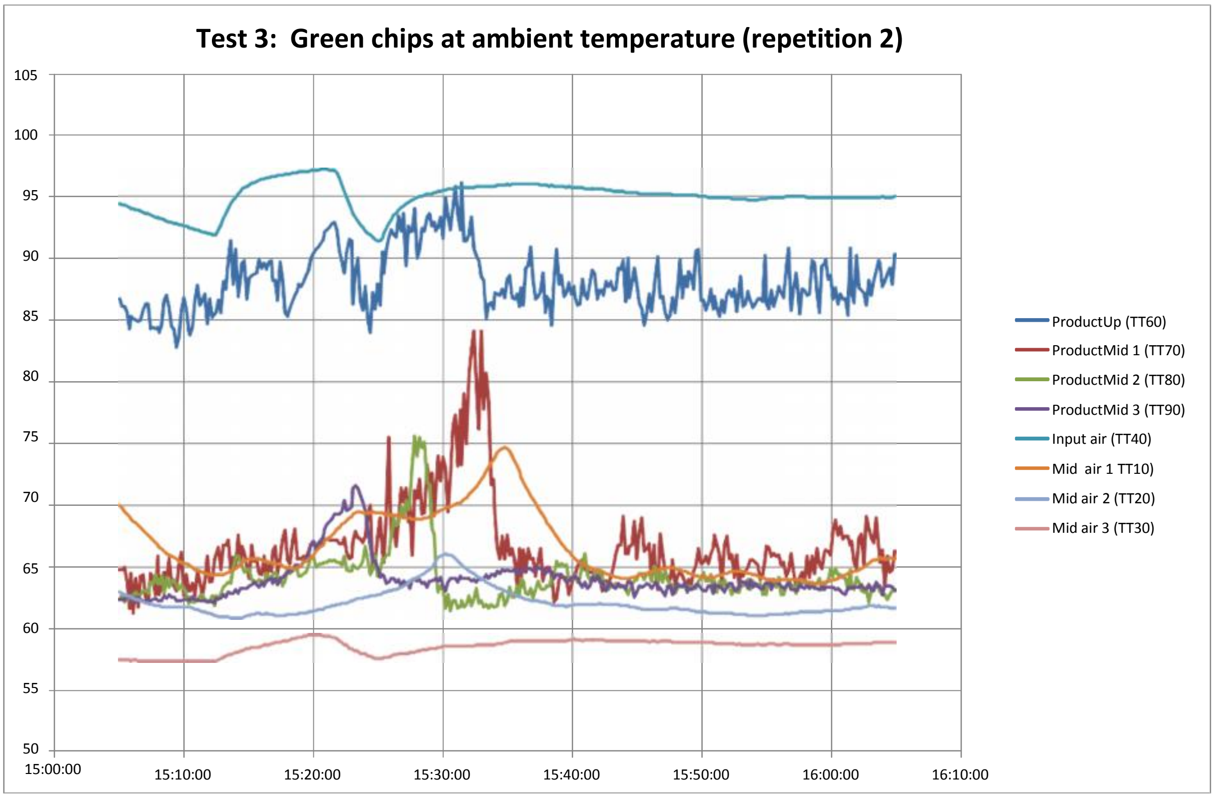


Figure 8 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 11 July 2016 during the period of presence of the larvae in the oven.

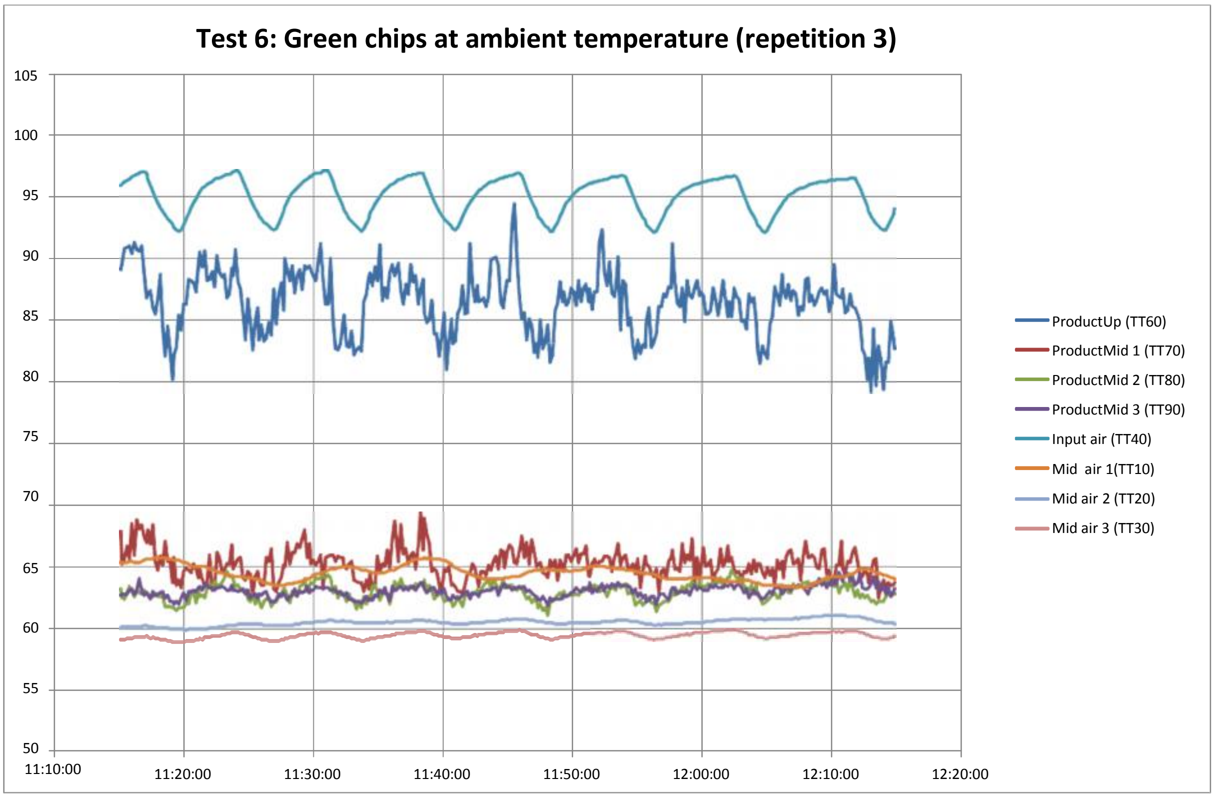


Figure 9 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 13 July 2016 during the period of presence of the larvae in the oven.

Test on dry chips at ambient temperature (tests 2, 4 and 5)

The treatment of the dry chips is theoretically easier as the thermal inertia of the latter is lower. The required temperature could be reached faster or, in other terms, the same initial energy of the input air would induce a higher temperature of the chips.

In contrast with the tests on the green wood where the 3 air temperature curves and the 3 product temperature curves were close in the lower stage, the differences are logically more marked here. In fact, when the green product was in the drying phase, the energy absorbed served to evaporate the water and the temperature of the product remained relatively constant. When the water was eliminated, the temperature of the product increased if the energy input was maintained.

The temperature of the chips was higher when these arrived on the lower disc, reaching 75 to 90°C, or even more. They cooled down during the 30 minutes of their presence on the disc, remaining at about 65°C, with particular situations where the output temperature exceeded 70°C.

The treatment of the dry chips was more difficult to regulate as the variations of the chips moisture content at the input were greater (variations from single to double possible). Despite that, to guarantee a treatment which complies with the requirements of ISPM15 was easy even if the temperature largely exceeded the requirements during several periods. In view of the temperatures reached, it is easy to understand that no larvae had survived the treatments.

In conclusion, the process is quite satisfactory for the treatment of dry chips at ambient temperature.

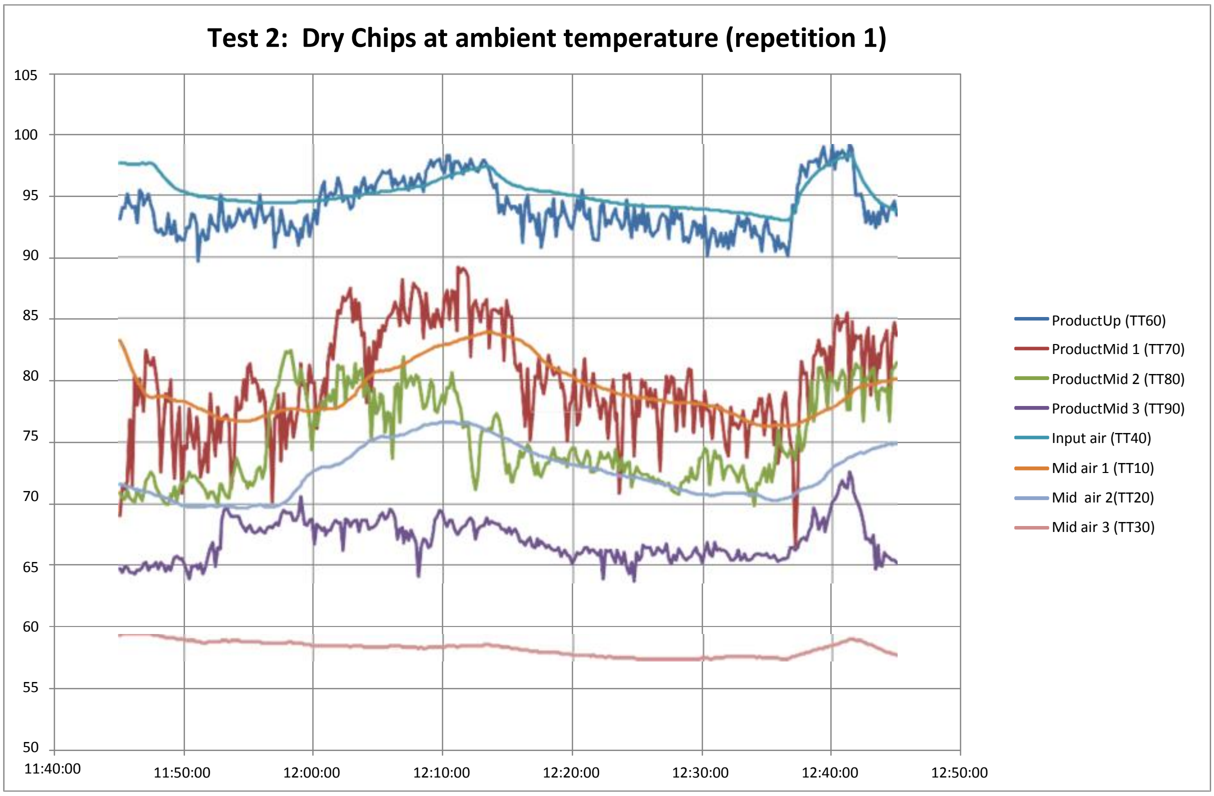


Figure 10 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 11 July 2016 during the period of presence of larvae in the oven.

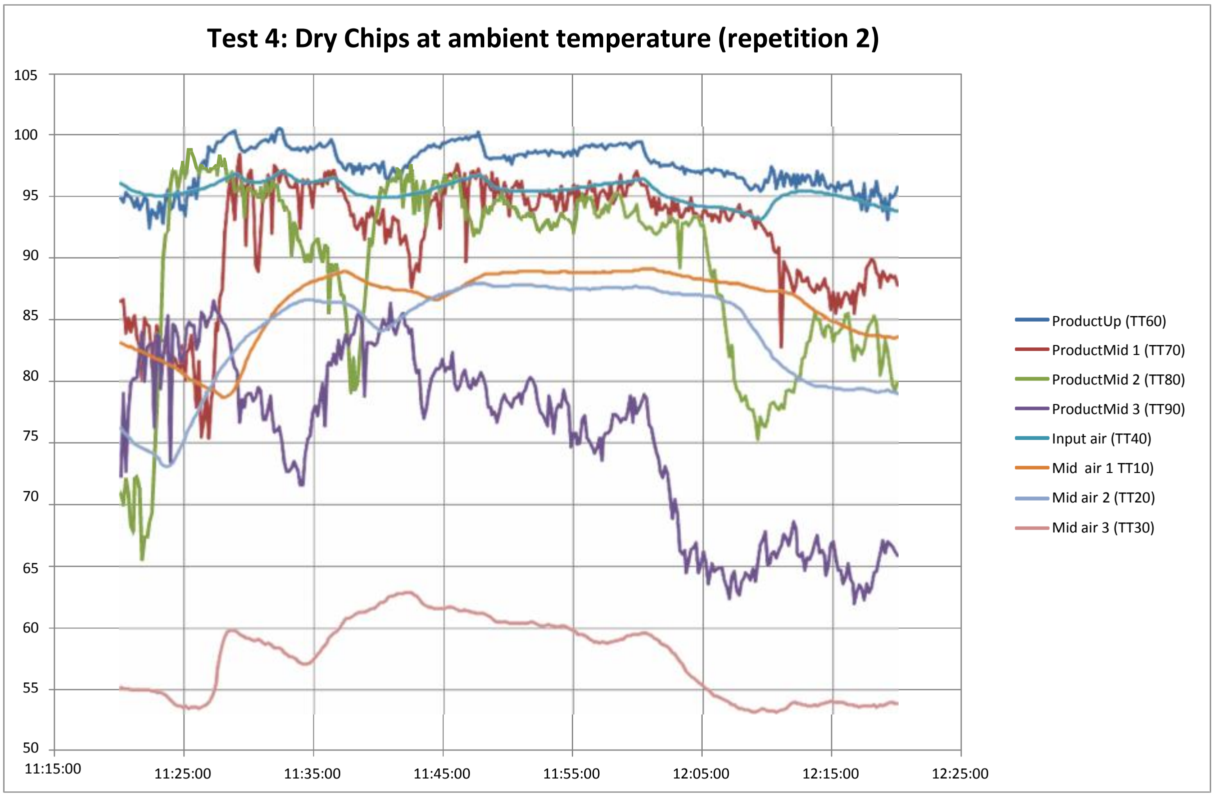


Figure 11 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 12 July 2016 during the period of presence of the larvae in the oven.

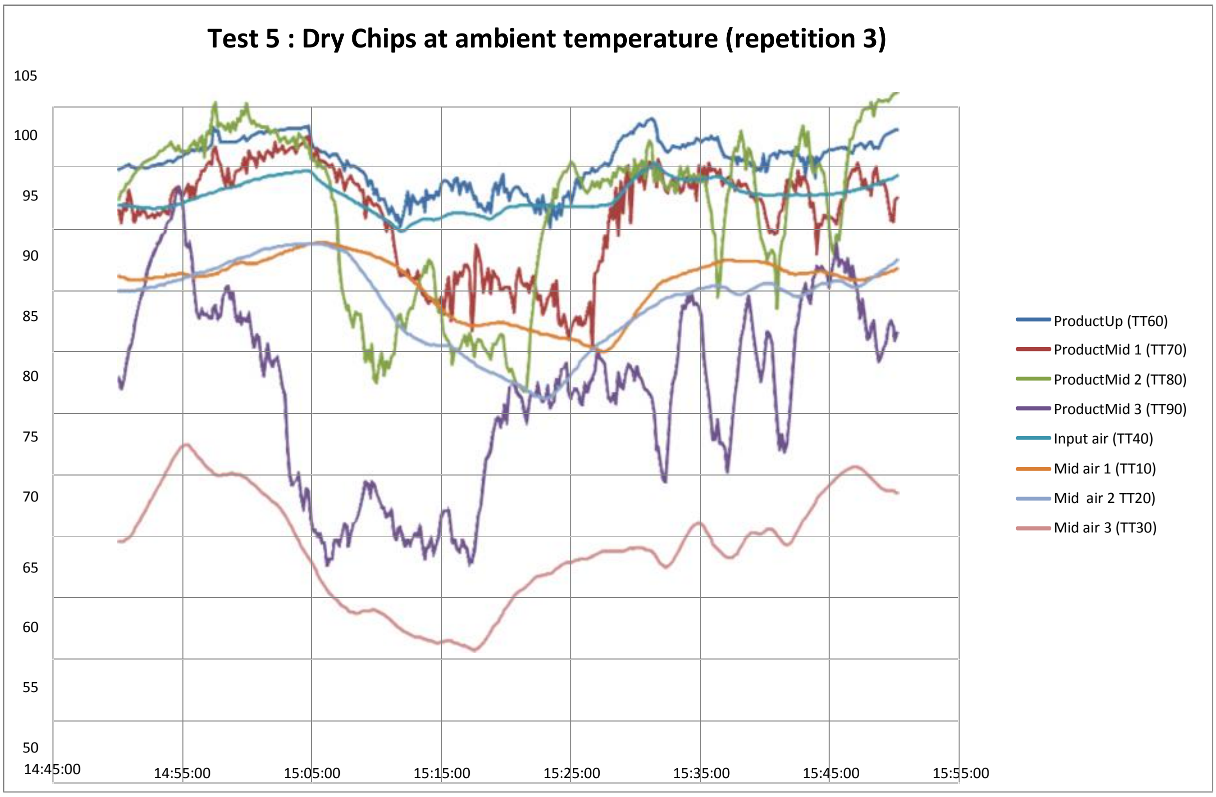


Figure 12 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 12 July 2016 during the period of presence of the larvae in the oven.

5.4 Analysis of the treatment tests for cooled chips

In order to encompass all the situations possible in the industrial practice, we considered the case where green chips, stored under winter conditions, would have to be treated. Under such circumstances, it seemed logical that the rise in temperature of the chips would be much slower and that the required core temperature would be difficult to obtain.

Two tests were performed to simulate these adverse conditions. Big-bags of green chips were cooled over 2 days, the 1st day at -15 °C to rapidly lower the temperature and the 2nd day at -5 °C so that the temperature in the centre of the bags would be around 0 to 5°C.

During the two tests, the initial temperature of the chips was about 5°C with small clusters still frozen (Photo 8).

Moisture content of the test specimens

	Repetition (test)	Before treatment	After treatment
Green specimens	1 (7) 2 (8)	131% 126%	100% 89%

Moisture content of the Chips

	Repetition (test)	Before treatment	After treatment
Green chips	1 (7) 2 (8)	98% 85%	20% 18%

Number of *H. bajulus* larvae by mass category

	Repetition (test)	0-50 mg	51-100 mg	101-150 mg	> 151 mg	Total
Green specimens	1 (7) 2 (8)	0 0	12 12	2 2	8 8	22 22

Mass of *H. bajulus* larvae (in mg)

	Average	Standard	Minimum	Maximum
Test 7	198	85	72	390
Test 8	198	83	61	354

The tests showed that the rise in temperature posed no problem. The variation of temperature of the chips at different measurement positions was relatively significant over time. However, the temperature of the raw material was always higher than 62°C over a time longer than 30 min since the temperature of 60°C was rapidly reached before leaving the upper disc. All the larvae introduced into the test specimens were killed by the treatment, while all the larvae kept at 5°C for 90 hours survived.

In conclusion, even in the case of very cold and green chips, the process allowed the requirements of ISPM15 to be met. Consequently, it was not necessary to multiply the tests since at no moment was the temperature of the raw material less than 60°C. It is obvious that if the process yields entirely satisfactory results with cold, green chips, *a fortiori*, the results would also be valid with cold, dry chips. In fact, the energy needs for reaching the same temperature would be lower since the quantity of water to heat and to evaporate would be much lower.

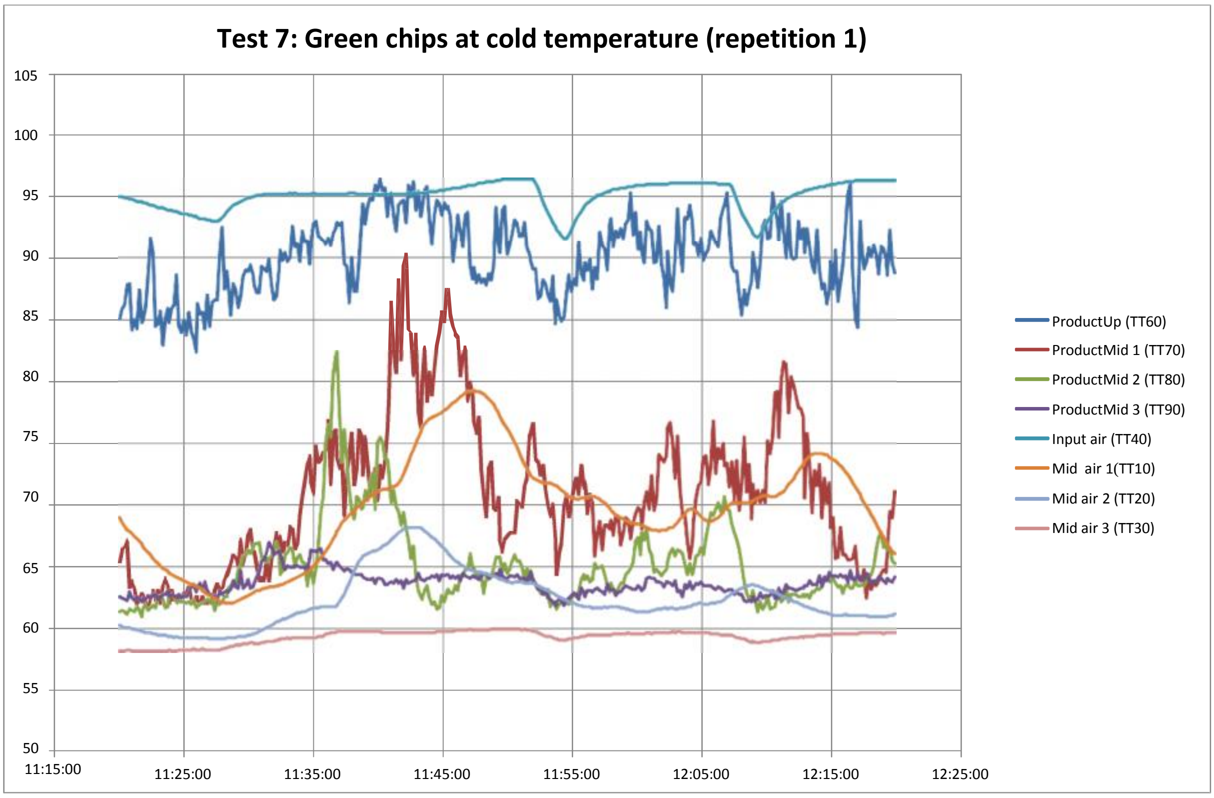


Figure 13 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 18 July 2016 during the period of presence of larvae in the oven.

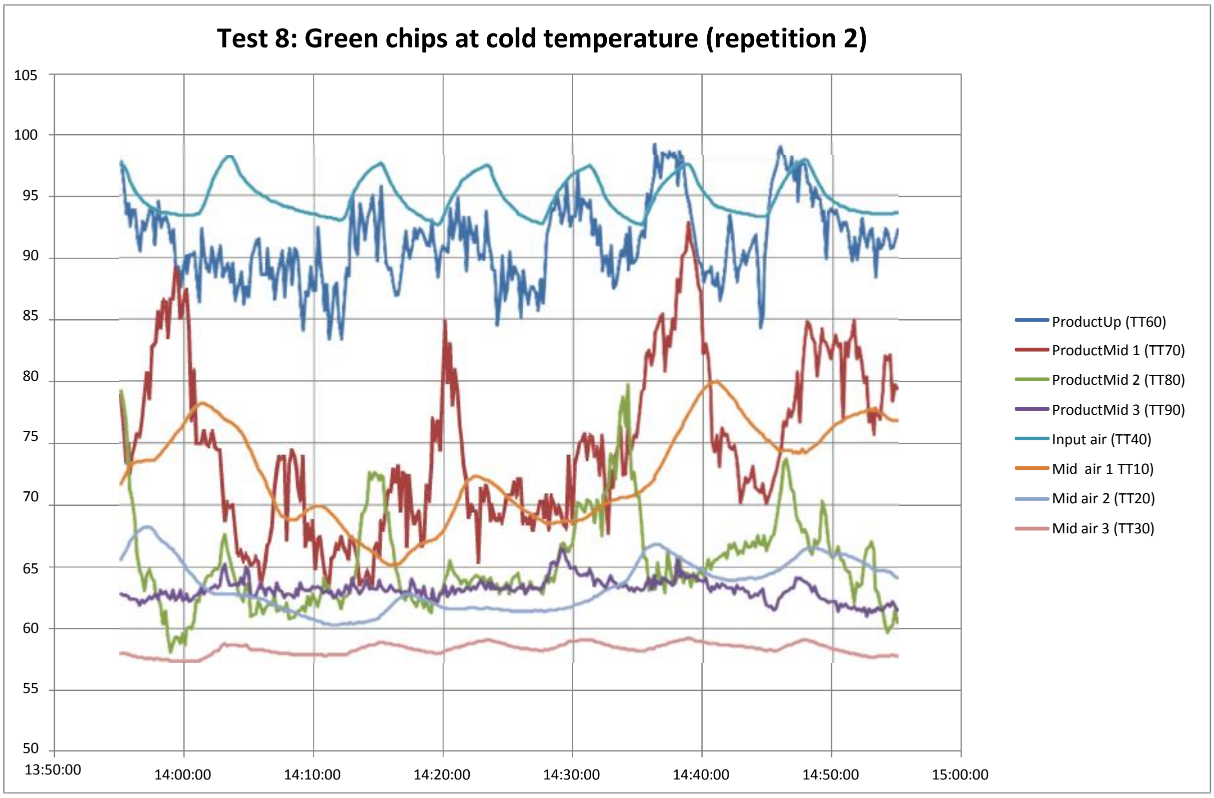


Figure 14 : Values recorded by the different temperature sensors (°C) as a function of time (hh:mm:ss) on 18 July 2016 during the period of presence of larvae in the oven.

5.5 Safety Margins

With regard to regulatory requirements, safety margins were taken to perfectly guarantee the relevance of the system. Thus:

- The target temperature is 60°C instead of 56°C in order to take account of the heterogeneity of the raw material (temperature, initial moisture content and thickness).
- The thermal insulation of the prototype used was of lesser quality than that of the commercialised machines.
- The reduced size of the prototype made it necessary to have a bucket elevator between the 2 discs, increasing the losses of heat and allowing the product to cool between the discs. This elevator is not present in the commercial models.
- The moisture content of the test specimens containing the larvae was higher than the moisture content of the chips.
- The wood specimens containing the insects were larger than the treated chips. It was more difficult therefore to heat them to the core and to kill the insects found there.
- The largest larvae used (and therefore the most resistant) could not be present in the chips of the size of those treated.

6 CONCLUSION AND RECOMMENDATIONS

All the tests confirm that under the experimental conditions tested, the ISPM15 requirements were always met: The temperature of the chips always exceeded 60°C on the surface during more than 30 minutes (which guarantees a core temperature of 56°C during 30 min) and no larvae survived the different treatments.

The tests were performed under variable conditions: dry wood and green wood, as well as green wood stored at a temperature close to 5°C (winter conditions).

The process tested therefore guarantees the effectiveness of the phytosanitary treatment and meets the technical conditions required for exporting wood chips.

The process was tested on a prototype. The industrial oven, larger but based on the same process, must offer the same guarantees of effectiveness. This will be confirmed by the continuous measurement of product temperatures at the input to the lower disc and the output from the same disc, 30 minutes later. The air temperature, also continuously measured, could confirm the treatment conditions.

The only restriction concerns the starting of the oven as the steady state conditions are not acquired immediately. For chips exiting the oven during the first 40 minutes of the first treatment cycle, the core temperature of 56°C, maintained for at least 30 minutes, cannot be guaranteed. Consequently, these chips must be recycled.

The effectiveness of the process and the proper operation of the oven are the conditions necessary to convince the sanitary authorities, but are probably not sufficient. Rigorous procedures must be implemented to ensure the traceability of the treated chips. The continuous recording of the physical parameters of the treatment associated with the continuous measurement of the flow rate of the treated chips, must accompany all batches of chips. This information could be recorded in real-time in a database that the phytosanitary authorities could consult. Other constraints could be imposed by the phytosanitary authorities. Under these conditions, contact with the Belgian, British and notably the American authorities concerning this point is highly recommended.

7 PHOTOGRAPHIC ANNEXES

7.1 Infra-red images

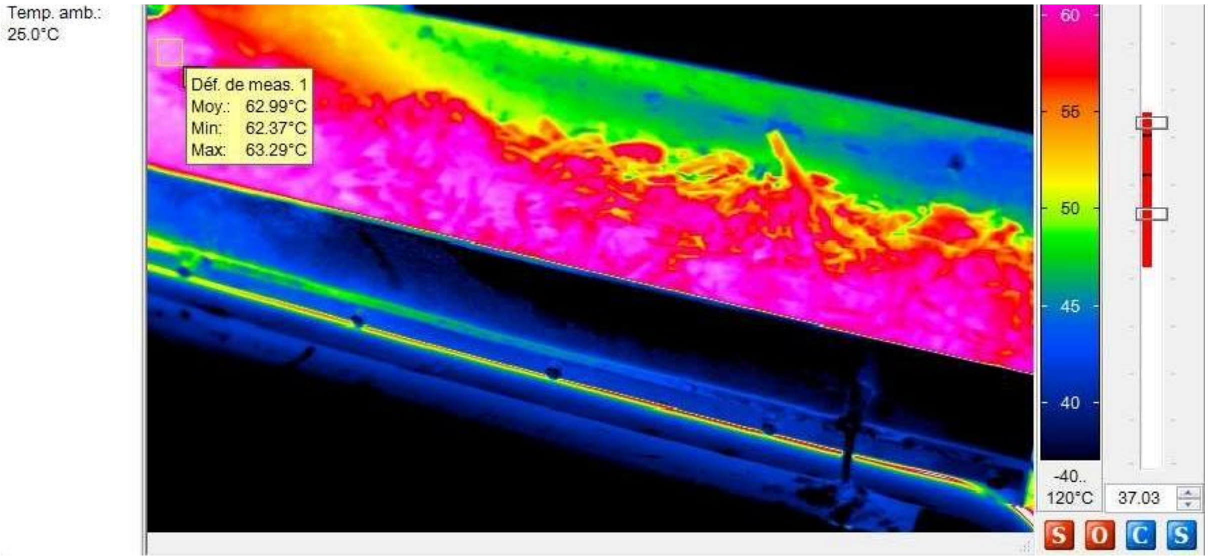
The tests were monitored with an infra-red camera in order to monitor the temperature of the chips at their output from the prototype on the conveyor belt.

The chips travel from left to right cooling in contact with the ambient air (±20°C). Each time, the output temperature of the chips reached at least 60°C. The infra-red images were set with an emissivity parameter of 0.9 (valid for wood). The temperature of the walls and other objects, not of interest here, are approximative.

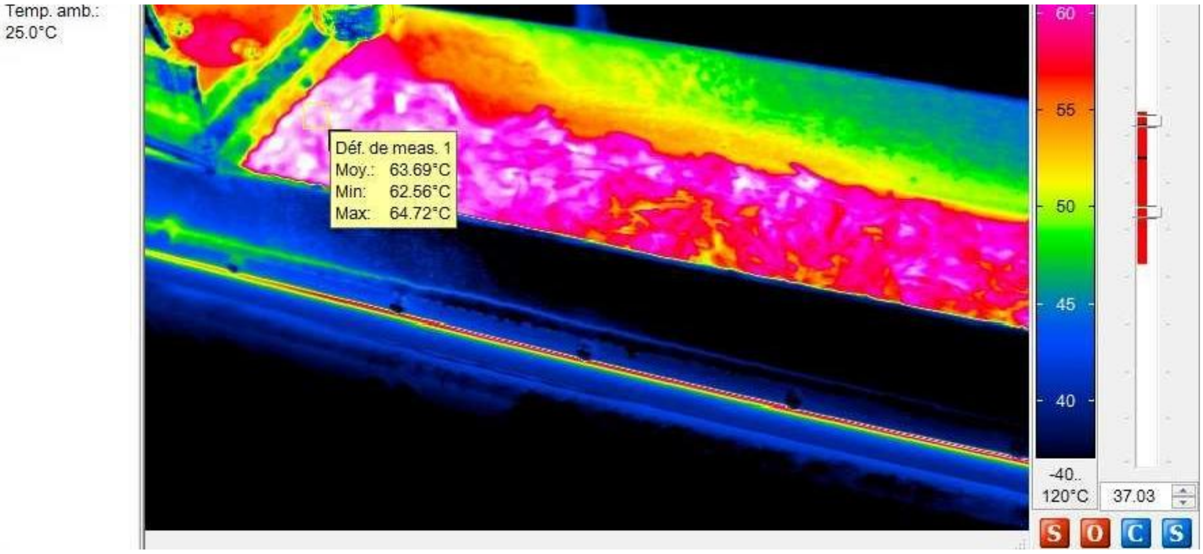
The photos are not classified in chronological order of the tests but organised, like the graphs, according to the experimental logic of the analyses described above.

Test 1: 1 July 2016 at 15h41 (to compare with the temperature graph of test 1).

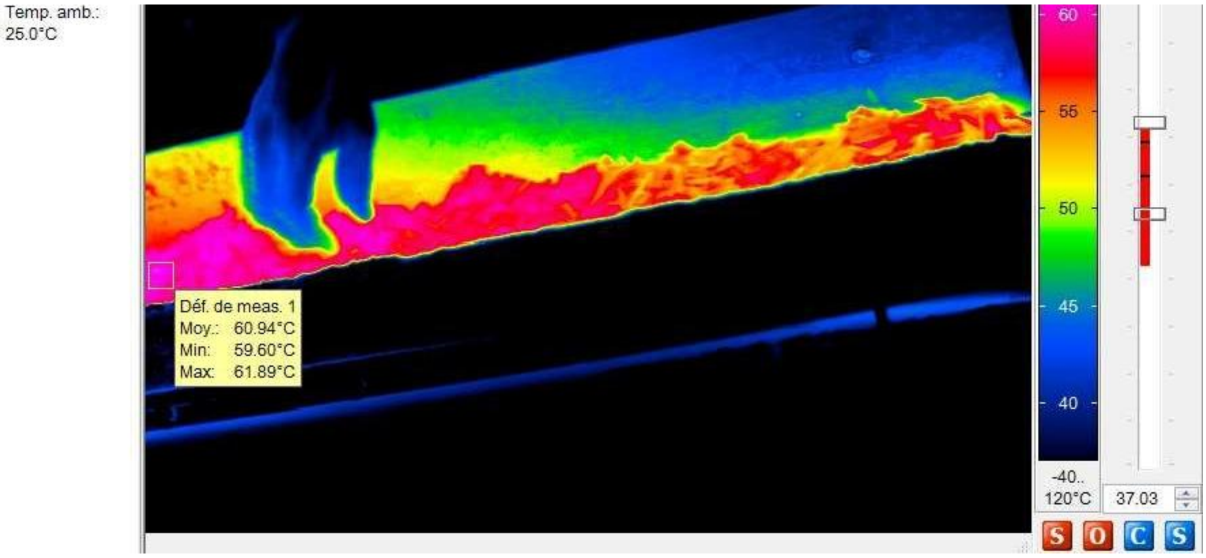
Green chips at initial ambient temperature (T°: 17/18°C - repetition 1)



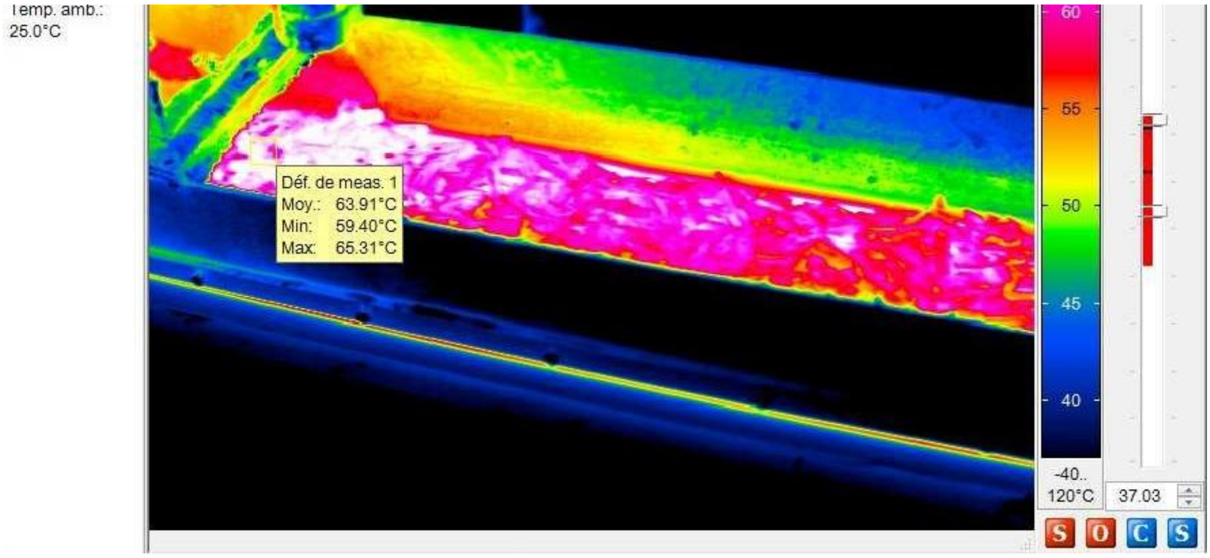
Test 3: 11 July 2016 at 15h39 (to compare with the temperature graph of test 3).
Green chips at initial ambient temperature (T°: 21/22°C - repetition 2)



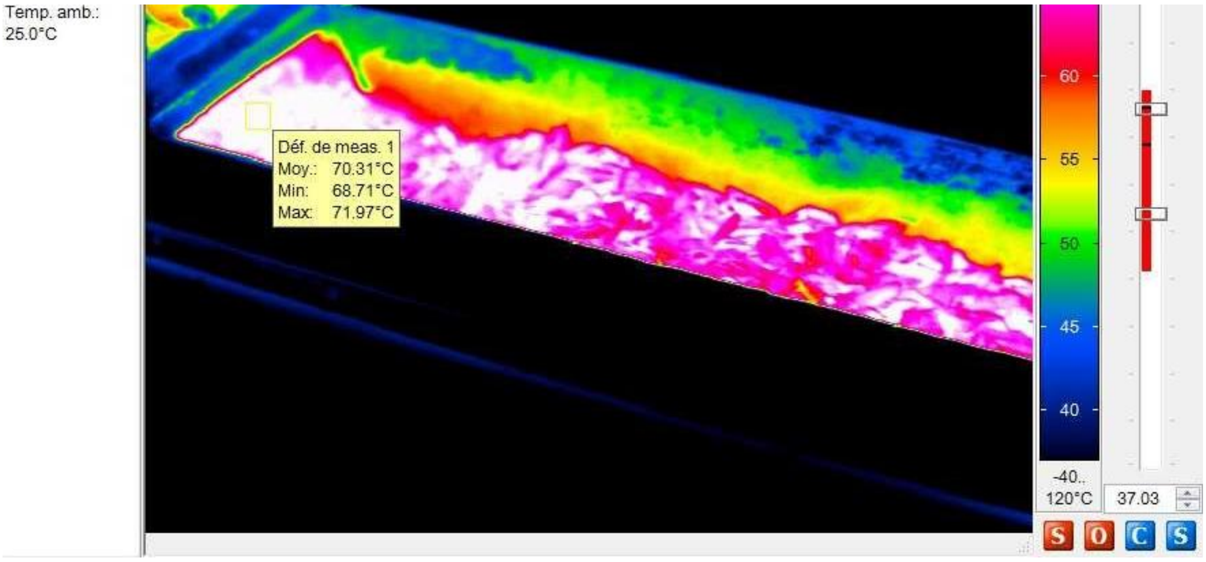
Test 6: 13 July 2016 at 11h36 (to compare with the temperature graph of test 6).
Green chips at initial ambient temperature (T°: 23°C - repetition 3)



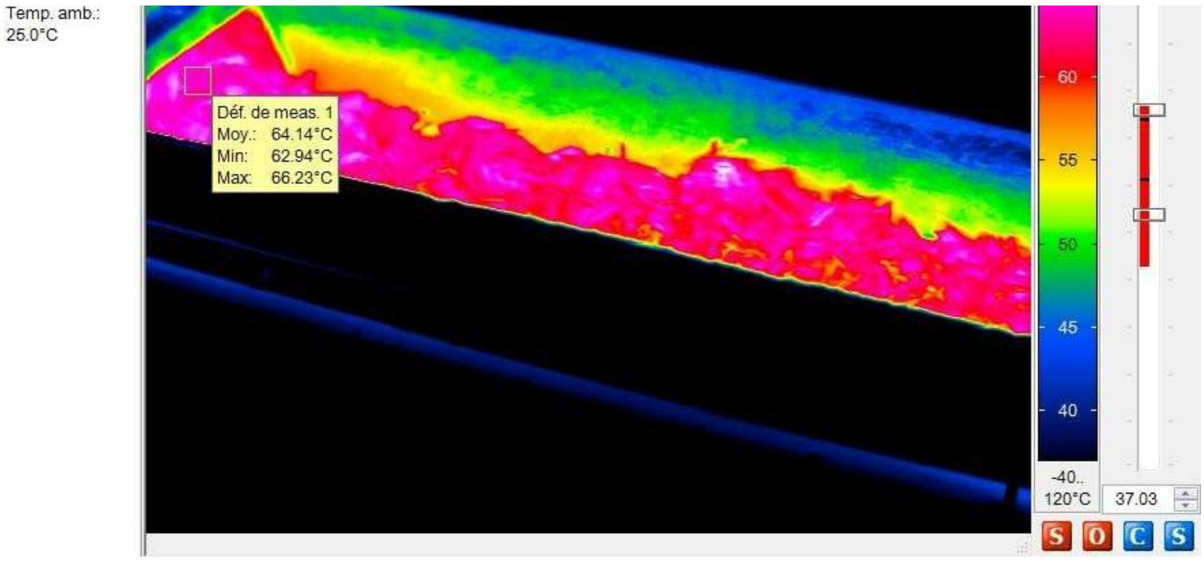
Test 2: 11 July 2016 at 12h08 (to compare with the temperature graph of test 2).
Dry chips at initial ambient temperature (T°: 21/22°C - repetition 1)



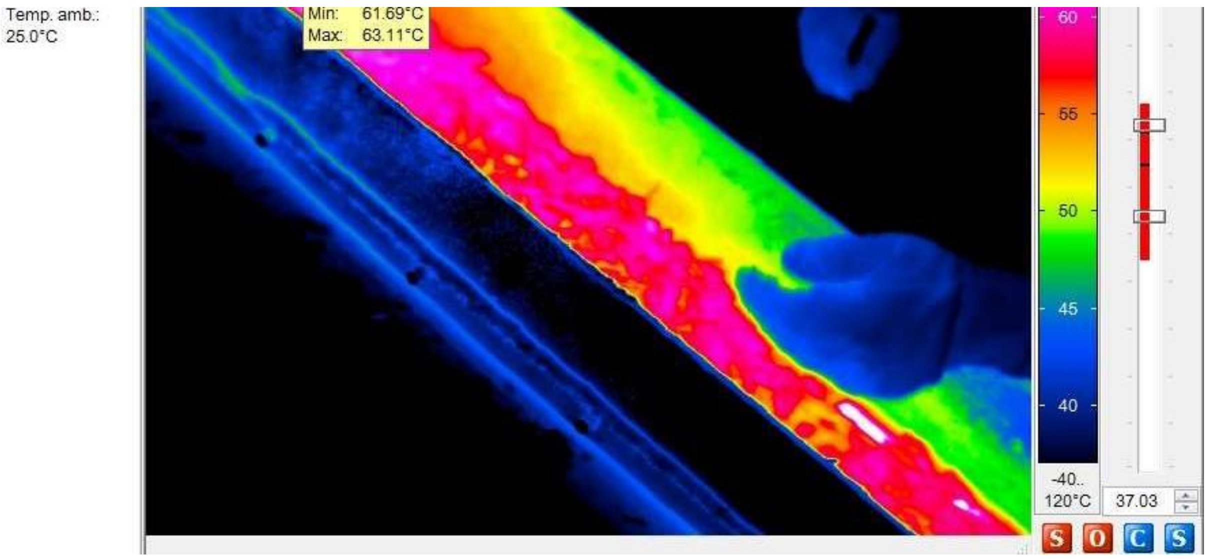
Test 4: 12 July 2016 at 11h57 (to compare with the temperature graph of test 4).
Dry chips at initial ambient temperature (T°: 22°C - repetition 2)



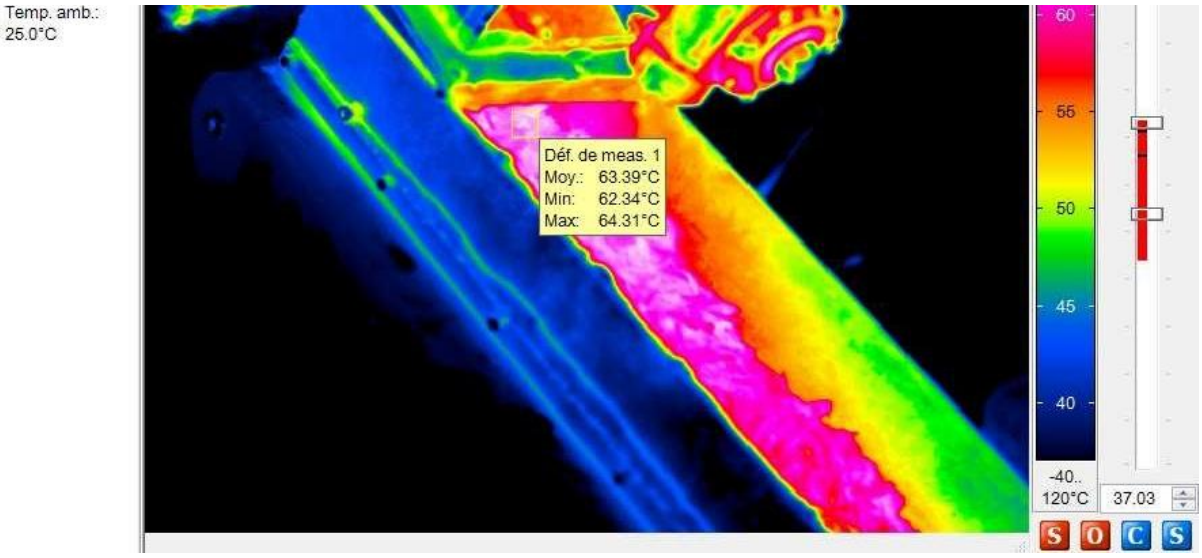
Test 5: 12 July 2016 at 15h12 (to compare with the temperature graph of test 5).
Dry chips at initial ambient temperature (T°: 23°C - repetition 3)



Test 7: 18 July 2016 at 11h56 (to compare with the temperature graph of test 7).
Green chips at low initial temperature (T°: 5°C - repetition 1)



Test 8: 18 July 2016 at 14h29 (to compare with the temperature graph of test 8).
Green chips at low initial temperature (T°: 5°C - repetition 2)



7.2 Photos of tests

Photo 1 : Experimental prototype adapted for the treatment of the chips

Photo 2: Chips packaged and stored in big bags prior to the test

Photo 3 : Preparation of the test specimens (larvae, precision balance and test specimens

Photo 4 : Introduction of a larva into a lodging drilled into the transverse face of the test specimen

Photo 5 : Sealing of the lodgements by means of a cotton plug, marking of the test specimens

Photo 6 : Weighing of the test specimens for the later determination of their moisture content

Photo 7 : Coloured test specimen on the left and closing of the lodging on the right

Photo 8 : Cluster of frozen chips

Photo 9 : Homogeneous layer of chips on the upper disc

Photo10 : Evacuation of the chips at the output of the oven on a conveyor belt

Photo 11 : Arrangement of the infra-red camera above the conveyor belt

Photo 12 : System of photography using an infra-red camera

Photo 13 : Recovery of the test specimens mixed with the chips

Photo 14 : Check of the operating parameters of the prototype

Views of the control screen (snapshots not to be interpreted alone)

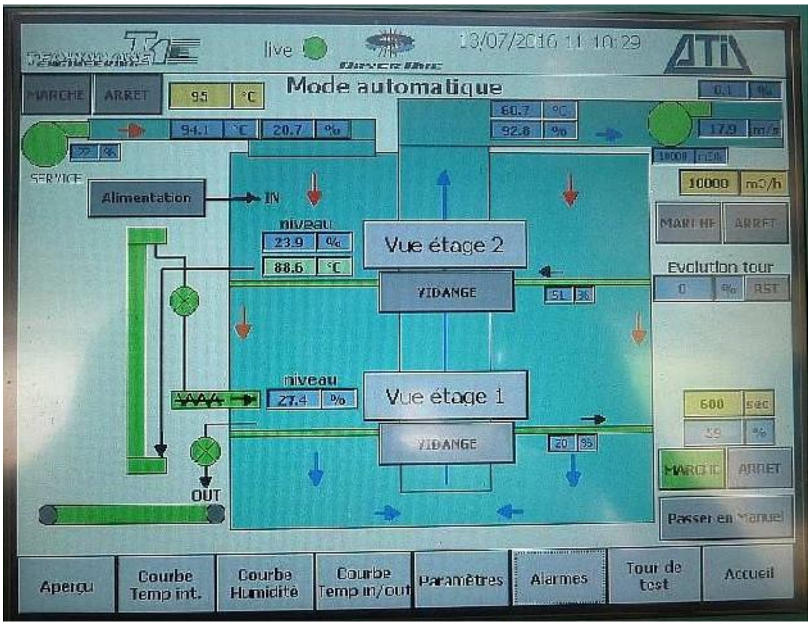


Photo 15 : Overall view of the operating parameters with the characteristics of the input air (in blue)

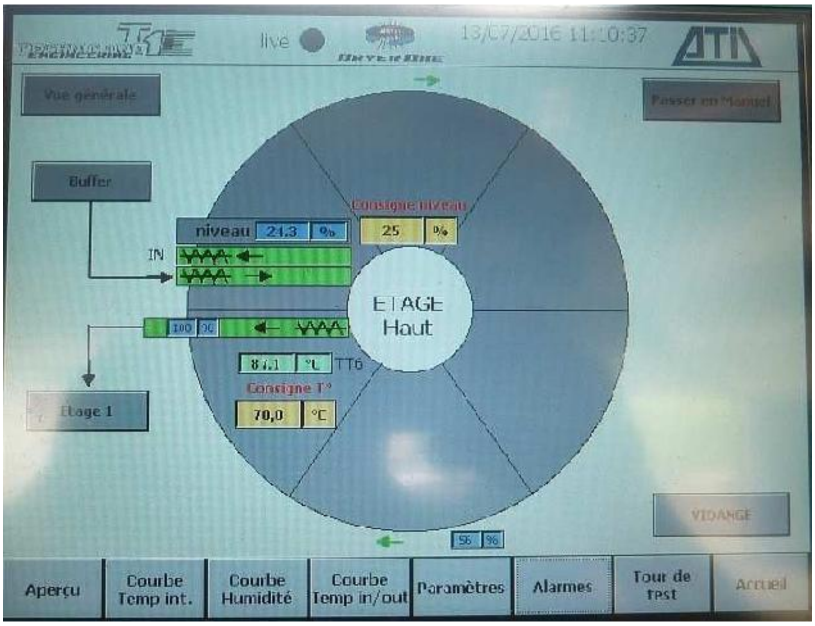


Photo 16 : View of the upper stage with the temperature of the product (in green)

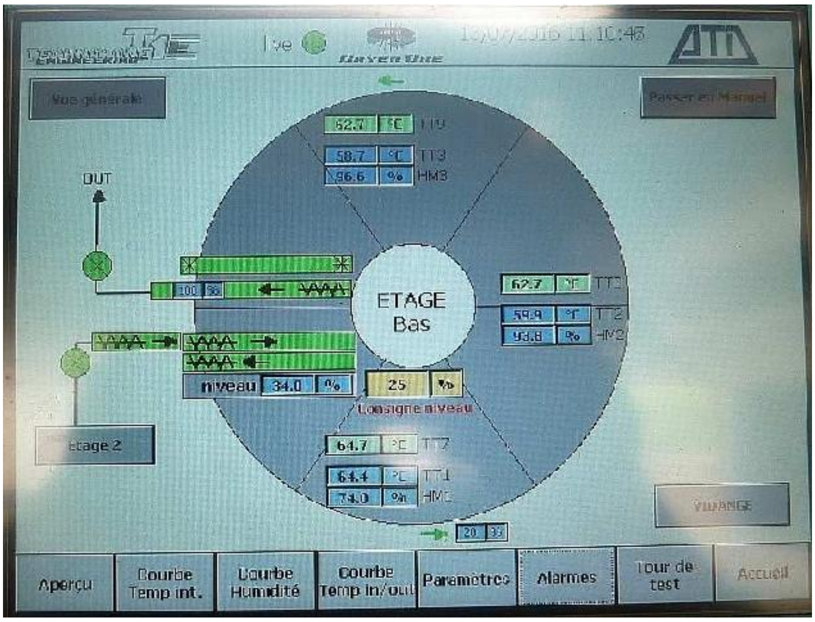


Photo 17 : View of the lower stage with the temperature of the product (in green) and the air characteristics (in blue)

8 TECHNICAL SHEETS FOR SENSORS

8.1 Technical sheet for infra-red thermometer sensors

22 Universal IR sensor for common applications

thermoMETER CT

thermoMETER CT

Non-contact IR temperature sensor for common applications

- Measuring range from -50°C to 975°C
- One of the smallest 22:1 infrared sensors worldwide
- Up to 85°C ambient temperature without cooling
- Separate controller with programming keys and backlit display
- Selectable and scalable analogue output, optional digital interfaces
- Exchangeable sensors
- Best price sensor

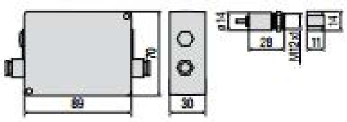
Optical specifications thermoMETER CT

□= smallest spot size (mm)

Standard Focus																
SF02	2:1	5	50	100	150	200	250	300	350	400						
	distance (mm)	0	100	200	300	400	500	600	700	800						
SF15	15:1	6.5	8.3	10	15	20	25	30	35	40	45	50	55	60	65	70
	distance (mm)	0	75	150	225	300	375	450	525	600	675	750	825	900	975	1050
SF22	22:1	6.5	8.3	10	15	20	25	30	35	40	45	50				
	distance (mm)	0	110	220	330	440	550	660	770	880	990	1100				
Close Focus (with optionally available CF lens)																
CF02	2:1	7	5	3.1	2.5	5.4	7.5	9.6	13.7	18						
	distance (mm)	0	10	20	23	30	35	40	50	60						
CF15	15:1	7	4	0.8	4.7	8.6	12.5	16.4	20.3	24.2						
CF22	22:1	7	4	0.6	4	8	12	16	20	24						
	distance (mm)	0	5	10	15	20	25	30	35	40						

Model		CT-SF02-C3	CT-SF15-C3	CT-SF22-C3
Optical resolution		2:1	15:1	22:1
Temperature range [1]		-50°C to 600°C	-50°C to 600°C	-50°C to 975°C
Spectral range		8 to 14µm		
System accuracy [2]		±1% or ±1°C		
Repeatability [2]		±0.5% or ±0.5°C		
Temperature resolution		0.1°C		
Response time		150ms (95%)		
Emissivity/gain [1]		0.100 to 1.100		
Transmissivity [1]		0.100 to 1.100		
Signal processing [1]		peak hold, valley hold, average; extended hold function with threshold and hysteresis		
Certificate of calibration		optional		
Outputs/analogue	channel 1	0/4 to 20mA, 0 to 5/10 V, thermocouple J, K		
	channel 2	sensor temperature (-20°C to 180°C as 0 to 5V or 0 to 10V), alarm output		
Outputs/analogue	optional	relay: 2 x 60VDC/42VAC; 0.4A; electrically isolated		
Outputs/digital	optional	USB, RS232, RS485, CAN, Profibus DP, Ethernet		
Output impedances	current output	mA max. 500Ω (with 8 - 36VDC)		
	voltage output	min. 100kΩ load impedance; thermocouple 20Ω		
Inputs		programmable functional inputs for external emissivity adjustment, ambient temperature compensation, trigger (reset of hold functions)		
Cable length		1m, 3m (standard), 8m, 15m		
Power supply		8 to 36VDC; max. 100mA		
Protection class		IP65 (NEMA-4)		
Ambient temperature	sensor	-20°C to 130°C	-20°C to 180°C	
	controller	0°C to 85°C		
Storage temperature	sensor	-40°C to 130°C	-40°C to 180°C	
	controller	-40°C to 85°C		
Relative humidity		10 to 95%, non condensing		
Vibration	sensor	IEC 68-2-6: 3 G, 11 to 200Hz, any axis		
Shock	sensor	IEC 68-2-27: 50 G, 11ms, any axis		
Weight		sensor: 40g; controller: 420g		

[1] adjustable via programming keys or software
[2] at ambient temperature 23 ±5 °C; whichever is greater



Product identification

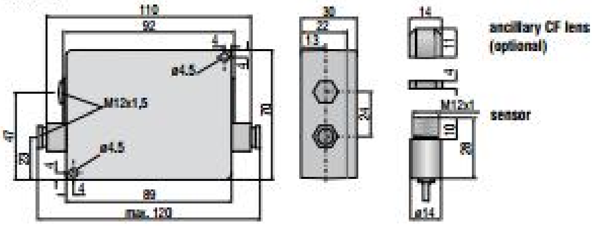
CT-	SF02-	C3
		Cable length [1m / 3m (standard) / 8m / 15m]
	Focus [SF02 / SF15 / SF22]	
thermoMETER CT		

Accessories page 40-43

- Ancillary CF lens
- Protective window
- Mounting bracket / Mounting bolt
- Air purge collar
- Right angle mirror
- Rail mount adapter for controller
- Massive housing
- Protective tube
- Laser sighting aid
- Digital-interface kits
- Accessories kit for use in Ex areas
- Certificate of calibration

CT / CTfast / CTM1/M2/M3

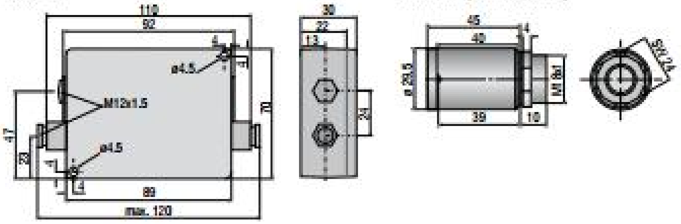
controller



CThot / CTP-3 / CTP-7

controller

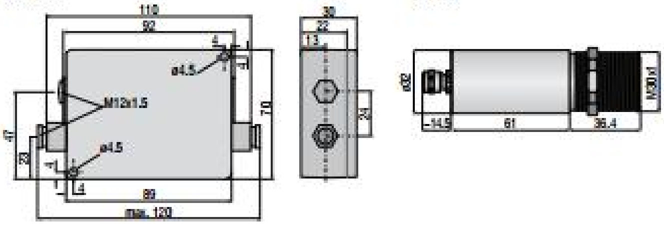
sensor with protective housing



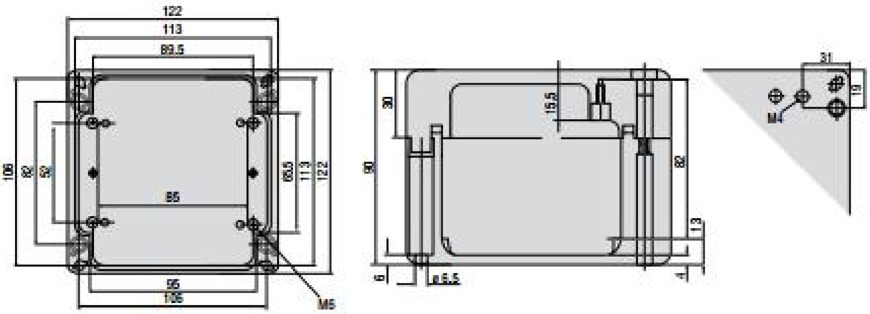
CTM3-XL

controller

sensor



CTex



8.2 Technical sheet for temperature and humidity sensors

TECHNICAL INFORMATION.

Factory Adjustment.

Two different adjustment profiles are available from the factory; this means that measurement accuracy can be matched to the application need. Calibration data is stored within the probe and can be retrieved later for audit purposes.

Probe Output Signal.

When connected to a PC the HygroClip2 probes can be rescaled with different ranges to suit the application need. It is also possible to assign the internally calculated dew or frost point value to one of these outputs; thus converting the HygroClip2 into a dew point probe.

Sensor Diagnostics.

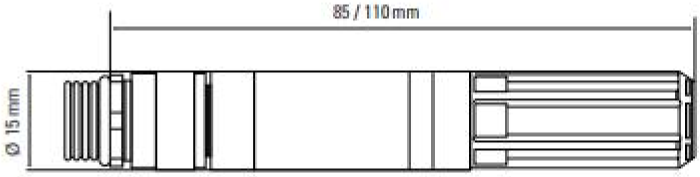
The intelligence of AirChip3000 technology enables advanced sensor diagnostics. Should the RH sensor deviate from factory defined parameters (for example because of chemical contamination) measurement values can be automatically compensated and a digital alarm triggered. The HygroClip2 probe can also be programmed to generate an alarm in the form of pre-defined analog output signals in the event of a problem with either the RH or temperature sensor. The user has full control over these features using ROTRONIC HW4 software.

Data Logging and Alarm Generation.

Up to 2,000 measurement values can be stored in the HygroClip2 probe; the user is able to configure the measurement interval, set alarm limits, scale the output signal and download data using optional ROTRONIC HW4 software. The HygroClip2 probe can be programmed with set limits to generate an alarm which is available when the probe is communicating with a PC or compatible ROTRONIC device. Thus, the HygroClip2 can be integrated in any application.

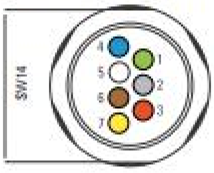
Humidity sensor	ROTRONIC Hygromer® IN-1
Temperature sensor	Pt100 class A (HC2-S) Pt100 1/3 class B (HC2-IC / HC2-IM / HC2-IE)
Accuracy with Standard adjustment profile	±0.8 %RH / ±0.1 K, at 10…30 °C at 23 °C und 10, 35, 80 %RH
Accuracy High Precision adjustment profile	±0.5 %RH / ±0.1 K, at 10…30 °C at 23 °C and 10, 20, 30, 40, 50, 60, 70, 80, 90 %RH
Long-term stability, humidity sensor	<1 %RH, 0.1 °C / year
Humidity response time τ63	<15 s, without filter
Measurement range	0…100 %RH, -100…200 °C[1] (depending on probe type)
Electronics operating range	-50…100 °C and 0…100 %RH
Analog output signals (standard, user scalable)	0…1 V = 0…100 %RH 0…1 V = -40…60 °C
Interface	UART
Accuracy analog output	±1 mV
Alarm function	Yes, analog & digital, programmable
Précision sortie analogique	±1 mV
Audit Trail / Electronic Records	FDA 21CFR Part 11 and GAMP compliant
Power supply	3.3…5 VDC
Current consumption	4.5 mA @3.3 VDC
IP protection	IP65
Housing/probe material	Polycarbonate , PEEK or stainless steel (depends on probe type)
Filter	Polyethylene / wire mesh filter
Standards	CE-compliant 2014/30/EU

[1] Short-term peak load



85 mm (plolycarbonate housing) / 110 mm (stainless steel housing)

Electrical connections:



1 V+
2 GND (digital and power)
3 RXD (UART)
4 TXD (UART)
5 Analog signal, humidity (0…100 %RH = 0…1 V)
6 Analog signal °C (-40…60 °C = 0…1 V)
7 AGND (analog ground)

rotronic
MEASUREMENT SOLUTIONS

ROTRONIC AG, Grindelstrasse 6, CH-8303 Bassersdorf, Tel. +41 44 838 11 44, www.rotronic.ch
ROTRONIC Instruments (UK) Ltd, Crompton Fields, Crompton Way, Crawley, West Sussex, RH10 9EE, UK, Phone +44 (0)1293 571000, www.rotronic.co.uk
ROTRONIC Instrument Corp, 135 Engineers Road, Hauppauge, NY 11788, USA, Phone, +1 631 427-3898, www.rotronic-usa.com
ROTRONIC Canada Inc., 236 Pritchard Rd, Unit 204, Hamilton, ON, Canada, L8W 3P7, Phone + 1 905 754-5164, www.rotronic.ca
ROTRONIC Instruments Pte. Ltd., 1003 Bukit Merah Central, #06-31 Inno Centre, Singapore 159836, Phone +65 6376 2107, www.rotronic.sg

59001E/2016-06

8.3 Technical sheet for air speed sensors

HD 2903T…, HD 29V3T…, HD 2937T…, HD 29V37T…
HD 29371T…, HD 29V371T…
TEMPERATURE, RELATIVE HUMIDITY AND AIR SPEED TRANSMITTERS

The family of transmitters series HD29 ... are employed in the control of air speed in the air conditioning and ventilation (HVAC / BEMS) in the pharmaceutical, museum, clean rooms, ventilation ducts, industrial sectors and households, crowded places, cafeterias, auditoriums, gymnasiums or on farms with large numbers of animals. The sensors in combination with an accurate electronics guarantee precise and reliable measurements in the time.

The sensor for the air speed is thin film, the probe sheath is AISI304, the filter relative humidity of 20μ wire mesh, materials that allow the use in hostile areas. There are two possible installations: in the TO version, the horizontal probe is joined to the electronics enclosure while in the TC version the probe is connected to the electronics through a cable.

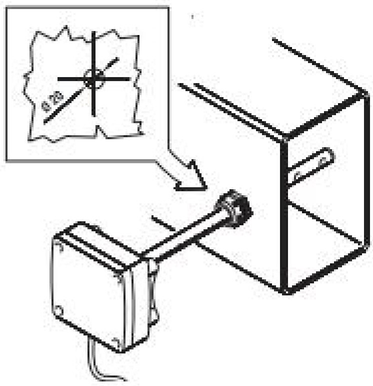
In the TO version, the duct probe is fixed to the electronics enclosure and it is available in three different lengths. To fix the probe to the duct, you can use, for example, the HD9008.31.12 flange, a 3/8" universal biconical connection or a PG16.12 metal cable gland (Ø10…14mm).

In the TC version, the probe together with the sensors is equipped with a cable which can be 2, 5 or 10 meters long. The probes are available in three different lengths.

Common technical specifications		Notes
Air speed Measuring range	0.05…1m/s 0.1…2m/s 0.20…10m/s 0.20…20m/s	The measuring range can be selected by dip-switch.
Air speed Accuracy range 0…1m/s range 0…2m/s range 0…10m/s range 0…20m/s	±(0.1m/s+3% of measurement) ±(0.15m/s+3% of measurement) ±(0.5m/s+3% of measurement) ±(0.7m/s+3% of measurement)	at 50%RH and 1013hPa
Temperature Measuring range	-10…+60°C	HD2937, HD29V37, HD29371 and HD29V371 models
Temperature Accuracy	±0.3°C	
Relative Humidity Measuring range	0…100%RH	HD29371 and HD29V371 models
Relative Humidity Accuracy	±1,5%RH (10…90%RH) ±2,0%RH (in the remaining range) for T= 15…35°C ---------------- ±(1,5+1.5% of the displayed value) %RH in the remaining temperature range	
Relative Humidity Output Range	0…100%RH	
Output (according to the models)	4…20mA 0…10Vdc	$R_L < 500\Omega$ $R_L > 10k\Omega$
Power supply	16…40Vdc or 12…24Vac±10%	
Response time (selected by jumper)	0.2s 2.0s	Fast Slow
Operating temperature electronics probe	0…+60°C -10…+80°C	
Compensation temperature	0…+80°C	
Storage temperature	-10…+70°C	
Electronics protection class	IP67	
Sensor working conditions	Clean air, RH<80%	
Case dimensions	80x84x44	Without probe

Model description

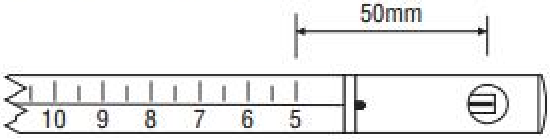
Model	Output		Measured parameters		
	4…20mA	0…10Vdc	Air speed	Temperature	Relative Humidity
HD2903T…	✓		✓		
HD29V3T…		✓	✓		
HD2937T…	✓		✓	✓	
HD29V37T…		✓	✓	✓	
HD29371T…	✓		✓	✓	✓
HD29V371T…		✓	✓	✓	✓



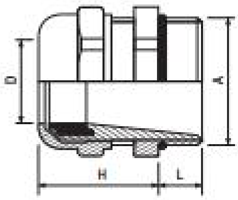
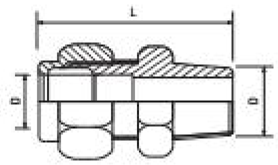
AS-24

Installation notes

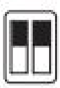
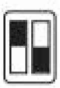
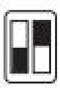
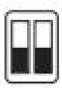
- The window of the sensor (or of the sensors) must be oriented in the direction of flow. To facilitate the proper positioning of the probe, eg. inside of a pipe, a graduated scale, engraved along the stem, indicates the depth of introduction of the window speed sensor in the channel. To properly orient the sensor to the flow, once introduced into the channel, the air speed window and line on the base of the scale are on the same axis.



- To fix the probe inside a ventilation duct, a pipe , etc. you can use, for example, HD9008.31.12 flange, a PG16.12 metal cable gland (Ø10…14mm) or a 3/8" universal biconical connection.

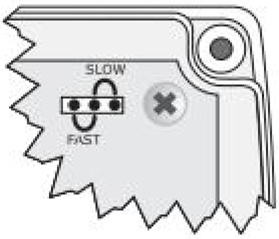
	**HD9008.31.12 Flange**
	**PG16.12 metal cable gland** D = 10…14mm L = 6.5mm H = 23mm A = PG16
	**Universal biconical connector** L = 35mm D = 14mm A = 3/8"

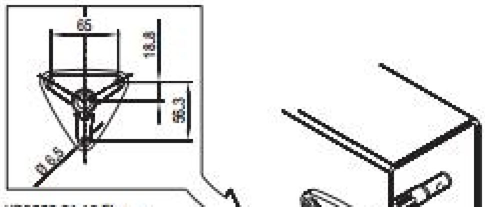
- The transmitters are factory calibrated and no further adjustments are required.
- To select the air speed **output range** by using the dual dip-switch on the board, please see the chart below:

Output range	0…1m/s	0…2m/s	0…10m/s	0…20m/s
Dip-switch position				

- Dip-switch should always be at the end of its final limit in both directions.

- The jumper on the board selects an **integrated response time in 0.2s in the FAST position and in 2s in the SLOW position. Please set the integration time at SLOW in case of turbulence, otherwise please select the FAST position.**





HD9008.31.12 Flange

Electrical connections

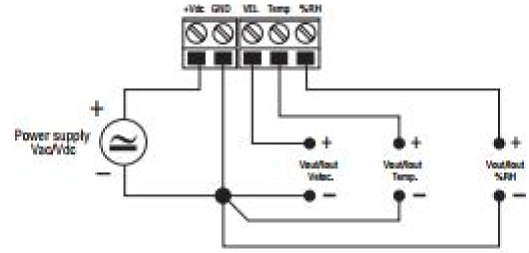
Power supply

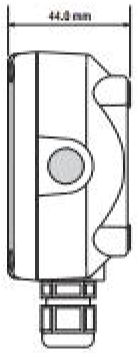
Power the instrument at the voltage shown in the electrical specifications: power supply terminals are marked as +Vdc and GND.

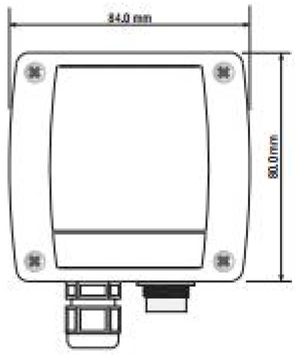
Analogue output

According to the model, the output signal comes from:

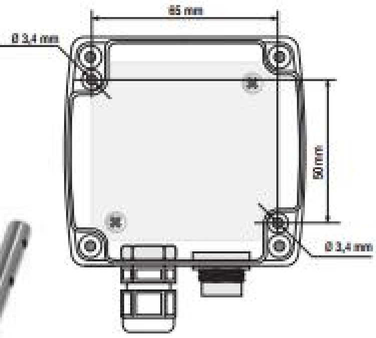
- VEL and GND terminals for air speed transmitters,
- VEL and GND, Temp and GND terminals for temperature / air speed transmitters,
- VEL and GND, Temp and GND, %RH and GND terminals for temperature / relative humidity / air speed transmitters.







Template



HD2903T… and HD29V3T… ORDERING CODES

HD2903T…: Active transmitter for measuring air speed in ducts, 4…20mA output. AISI 304 steel probe, diameter 12mm, compact unit HD2903TO… version with probe joined to the electronics enclosure, HD2903TC… version with probe connected to the electronics through a cable. Air speed range 0.05…1m/s - 0.1…2m/s - 0.20…10m/s - 0.20…20m/s selected by jumper. Power supply 16...40Vdc or 12…24Vac. Air probe operating temperature -10…+80°C.

HD29V3T…: Active transmitter for measuring air speed in ducts, 0…10Vdc output. AISI 304 steel probe, diameter 12mm, compact unit HD29V3TO… version with probe joined to the electronics enclosure, HD29V3TC… version with probe connected to the electronics through a cable. Air speed range 0.05…1m/s - 0.1…2m/s - 0.20…10m/s - 0.20…20m/s selected by jumper. Power supply 16...40Vdc or 12…24Vac. Air probe operating temperature -10…+80°C.

H D 2 9 [ ] 3 T [ ] [ ]

- Cable length (… TC … models only)
  - 2 = 2m
  - 5 = 5m
  - 10 = 10m
- Probe length
  - T01 = 150mm
  - T02 = 250mm
  - T03 = 350mm
  - TC1 = 145mm
  - TC2 = 245mm
  - TC3 = 345mm
- 3 = Air speed
- 0 = 4…20mA analogue output
- V = 0…10Vdc analogue output

HD2937T… and HD29V37T… ORDERING CODES

HD2937T…: Active transmitter for measuring air speed and temperature in ducts, 4…20mA outputs. AISI 304 steel probe, diameter 12mm, compact unit HD2937TO…version with probe joined to the electronics enclosure, HD2937TC…version with probe connected to the electronics through a cable. Air speed range 0.05…1m/s - 0.1…2m/s - 0.20…10m/s - 0.20…20m/s selected by jumper, fixed temperature range -10…+60°C. Power supply 16...40Vdc or 12…24Vac. Air probe operating temperature -10…+80°C.

HD29V37T…: Active transmitter for measuring air speed and temperature in ducts, 0…10Vdc outputs. AISI 304 steel probe, diameter 12mm, compact unit HD29V37TO…version with probe joined to the electronics enclosure, HD29V37TC… version with probe connected to the electronics through a cable. Air speed range 0.05…1m/s - 0.1…2m/s - 0.20…10m/s - 0.20…20m/s selected by jumper, fixed temperature range -10…+60°C. Power supply 16...40Vdc or 12…24Vac. Air probe operating temperature -10…+80°C.

H D 2 9 [ ] 3 7 T [ ] [ ]

- Cable length (… TC … models only)
  - 2 = 2m
  - 5 = 5m
  - 10 = 10m
- Probe length
  - T01 = 180mm
  - T02 = 275mm
  - T03 = 375mm
  - TC1 = 175mm
  - TC2 = 275mm
  - TC3 = 375mm
- 7 = Temperature output
- 3 = Air speed
- No sign = 4…20mA analogue output
- V = 0…10Vdc analogue output

HD29371T… and HD29V371T… ORDERING CODES

HD29371T…: Active transmitter for measuring air speed, temperature and relative humidity in ducts, 4…20mA outputs. AISI 304 steel probe, diameter 14mm, compact unit HD29371TO version… with probe joined to the electronics enclosure, HD29371TC… version with probe connected to the electronics through a cable. Air speed range 0.05…1m/s - 0.1…2m/s - 0.20…10m/s - 0.20…20m/s selected by jumper, fixed temperature range -10…+60°C, relative humidity range 0…100%RH. Power supply 16...40Vdc or 12…24Vac. Air probe operating temperature -10…+80°C.

HD29V371T…: Active transmitter for measuring air speed, temperature and relative humidity in ducts, 0…10Vdc outputs. AISI 304 steel probe, diameter 14mm, compact unit HD29V371TO…version with probe joined to the electronics enclosure, HD29V371TC… version with probe connected to the electronics through a cable. Air speed range 0.05…1m/s - 0.1…2m/s - 0.20…10m/s - 0.20…20m/s selected by jumper, fixed temperature range -10…+60°C, relative humidity range 0…100%RH. Power supply 16...40Vdc or 12…24Vac. Air probe operating temperature -10…+80°C.

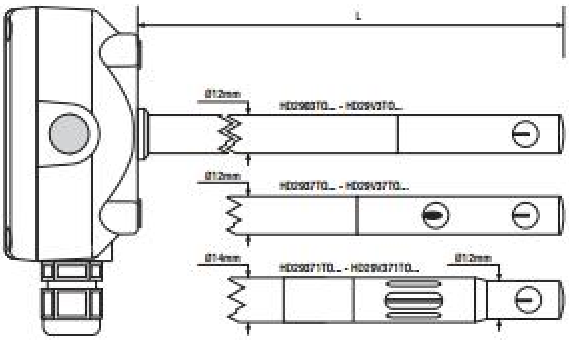
H D 2 9 [ ] 3 7 1 T [ ] [ ]

- Cable length (… TC … models only)
  - 2 = 2m
  - 5 = 5m
  - 10 = 10m
- Probe length
  - T01 = 215mm
  - T02 = 415mm
  - T03 = 565mm
  - TC1 = 215mm
  - TC2 = 415mm
  - TC3 = 570mm
- 1 = %RH output
- 7 = Temperature output
- 3 = Air speed
- No sign = 4…20mA analogue output
- V = 0…10Vdc analogue output

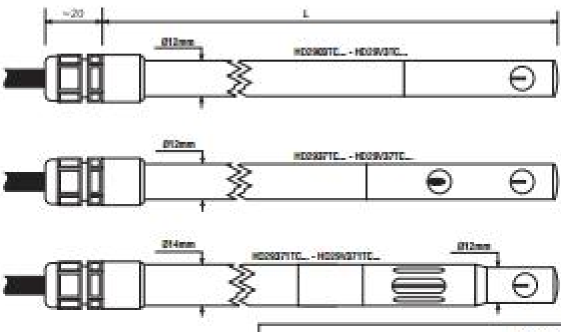
Air speed

Probe dimensions:

TO series



TC series



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Henin J.-M., Bauduin A., Leyman M., Jourez B., Hébert J. (2012). Microwave-treatment of frozen wood packaging material. Joint IRG – IUFRO Research Sessions, International Union of Forest Research Organizations, All Division 5 Conference, Estoril, Portugal, 8-13 July 2012.

Henin J.-M., Leyman M., Bauduin A., Jourez B., Hébert J. (2014). Phytosanitary treatment of European pallets by microwave: developing a program to ensure compliance with ISPM 15 and monitoring its efficacy on the house longhorn beetle (*Hylotrupes bajulus L.*). *Eur. J. Wood Prod.* 72(5): 623-633.

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