

11 - Heat treatments, state of the technology

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Abstract

From over 400 uses of the ThermoNox system in various customer environments a wealth of experience has been accumulated. Additionally, extensive knowledge on using heat as an insect control method was gained through biological research over the last years. Collaboration with a number of engineers and plant constructors with regard to the suitability for heat treatments of buildings and different installations used in the food processing and other industries has confirmed the technical feasibility of this approach, within certain defined limits. Particular characteristics of thermal treatments in general and the ThermoNox system in particular are outlined, the efficacy as well as the limitations of the technology are shown based on theoretical considerations and practical key figures.

An outlook into the premises to a wider use of thermal methods in the future is discussed, as are opposing factors.

Introduction

For the treatment of stored product pests in buildings, empty silos and storages as well as in food production premises preventive measures have gained enormous importance. Especially cleaning and maintenance of buildings and processing equipment has proven efficient, as these measures can significantly reduce the amount of available food and harbourages. Unfortunately, due to their nature, production residues (dusts) can enter deep into the fabric of a building and into dead space inside machinery. Even the most diligent cleaning can not sufficiently remove these residues because they are not physically accessible.

It is these deep seated sources of latent infestations that cause the necessity for regular treatments. Only two treatment methods can be applied in order to eradicate (= kill pest insects in all development stages) deep seated infestations: fumigation with toxic fumigants and the application of high temperatures. This essay deals with heat treatments.

Thermal treatment: The application of extreme heat intended to kill stored product insects is a relatively old technology, but could not really get a hold in the market since it was replaced by the (fast and relatively cheap) use of toxic fumigants throughout the past decades.

Over ten years ago ThermoNox was introduced and has been put to use in more than 400 premises to-date. During these years knowledge gaps were filled in and a wealth of experience in the practical application has been collected.

Critical questions concerning the efficacy of heat treatments and mortalities of a variety of common SPI can today be answered, thanks to fundamental works done by C. Adler (2005) (Tab.1).

Tab. 1 Lethal effects on heat on various insects

Species		45 °C	50 °C	55 °C
Grain weevil	<i>S. granarius</i>	540 min (9 h) (L)	40 min (L)	30 min (L)
Corn weevil	<i>S. zeamais</i>	660 min (11 h) (L)	45 min (A)	30 min (A)
Flat grain beetle	<i>C. pusillus</i>	1200 min (20 h) (L)	65 min (L)	20 min (L)
Red flour beetle	<i>T. castaneum</i>	1800 min (30 h) (L)	35 min (L)	20 min (L)
Tobacco beetle	<i>L. serricorne</i>	2400 min (40 h) (L)	370 min (U)	45 min (U)
Lesser Grain Borer	<i>R. dominica</i>	6000 min (100 h) (L)	370 min (L)	45 min (L)

In brackets the most sound stadium: E = egg, L = larvae, A = adult beetle

Source: www.bba.de

Additionally, reasons for failure, limitations of the technology and causes for building damage were addressed in order to avoid future problems. Time and energy requirements as well other cost relevant parameters can now be properly calculated and prognosticated.

What can go wrong during a heat treatment?

- Various physical processes may occur during a thermal treatment, namely:
- Reversible / irreversible deformation due to unequal temperature (homogenous material)
- Reversible / irreversible deformation due to unequal extension (different material)
- Evaporation of components: water, softeners etc.
- Reduction of strength: modules of draw, pressure
- Initiation of phase transitions
- Initiation of chemical reactions

In order to avoid damages due during warming of different materials, their respective coefficients of extension have to be regarded. Some important coefficients are shown in Tab. 2:

Tab. 2 Thermal coefficient of extension (B. Keller, 2005)

Concrete	$10 \cdot 10^{-6} \text{ K}^{-1}$
Brick	$6 \cdot 10^{-6} \text{ K}^{-1}$
Wood	$15 \cdot 10^{-6} \text{ K}^{-1}$
Steel	$12 \cdot 10^{-6} \text{ K}^{-1}$
Aluminium	$24 \cdot 10^{-6} \text{ K}^{-1}$
Glass	$9 \cdot 10^{-6} \text{ K}^{-1}$
Plastic materials	$80 - 200 \cdot 10^{-6} \text{ K}^{-1}$

It is vitally important that combined materials with differing extension coefficients are capable of extending independently – care should be taken to separate (e.g. loosen or remove locks, screws, etc.) such materials wherever possible.

The deformation of a slab of concrete due to difference in temperature is shown in the following:

Concrete slab:

- Thickness: 30 cm, Difference in temp.: 40 K, $a = 10 \cdot 10^{-6} \text{ K}^{-1}$, length: 10 m
- Difference in extension: 4 mm
- Radius of curvature: 750 m
- Strength: $14 \text{ N} / \text{mm}^2 \ll \text{compressive strength } (30 - 50 \text{ N} / \text{mm}^2)$

Occurring differences in temperature are not critical:

- No cracking
- No unacceptable deformation
- Time too short for dehydration

Wood behaves in a characteristic way when heated, in general it can be stated that:

- wood is very temperature resistant
- thermal extension is anisotropic (natural wood)
- wood warps ("works") below 30% r.h.
- wood is strongest deformed by dehydration \gg thermal deformation
- thermally occurring forces \ll compressive strength
- close to wooden installations is necessary: r.h. $> 30\%$

According to (B. Keller, 2005) different plastic materials display the following behavior:

- **Duroplastics:** non soften, non melt, decompose only at $T > 100^\circ\text{C}$ (epoxy, polyester, Teflon, "Bakelite")
- **Thermoplastics:** can soften, glass point, melt only at $T > 100^\circ\text{C}$ (PU, PE, PVC etc)
- **Elastomers:** are already soft elastic, decompose only at $T > 100^\circ\text{C}$ (gum, caoutchouc)

Some thermoplastics have a softening temperature in the range of between 50-60°C (heat treatment):

- They can soften: Permanent impressions by resting vertical load.
- Susceptible to shear stress: particular adhesives, soft-PE, soft-PVC
- Plastic materials: Duroplastics, elastomeres and most thermoplastics do not pose a problem below 60°C.

Conclusions for heat treatments:

- Most of the widely used materials are heatable to 55 – 60 °C without problems
- The duration of 24 – 48 h is too short for causing structural damage
- As a precaution: preceding tests can be helpful
- The presence of wood requires humidification

Usually, thermal treatments follow three phases: heating, maintaining target temperature, and cooling.

Heating phase: Energy requirements are highest during the heating phase because all materials of a building including everything inside has to be brought up to the target temperature. During this phase heat is carried exclusively by the air inside the building. Room air is heated not once but is recycled through the heating apparatus, thus kept at the maximum achievable temperature. Since the specific warmth in air is relatively poor high volumes of air have to be circulated.

Heat transmission from air on to a solid body (i.e. building material, equipment, machinery and, subsequently, infested residues) is described with this formula:

$$Q = \alpha A t \Delta\delta$$
$$\alpha \text{ (air on smooth surface, } v < 5 \text{ m/s)} = 5.6 + 4 v$$

The amount of warmth transmitted through surface A is directly dependent on the heat transmission coefficient α , the duration of transmission t and the temperature gradient between the heated room air and the surface of the object to be heated $\Delta\delta$.

On the right of the equation two values appear given: A the surfaces and $\Delta\delta$ the temperature difference. Since the temperature of the room air must not exceed 60°C the maximum temperature difference can be regarded given. Adjustable are only α , contained within the air velocity v. The time needed for the heating phase t is derived from the other parameters.

Conclusions for a safe thermal treatment:

- Room air max. 60°C , heated through recirculation
- Move heated air with a high velocity to reduce overall heating up time
- Distribute heated air evenly throughout the treatment area to ensure a synchronous, slow and therefore secure heating of everything inside the area
- Avoid local overheating (possible damage!), this requires a sufficiently exact temperature control in the heat generating equipment

Buildings, machinery and other equipment are made from different material, taking up, storing and conveying heat at different rates. This means that there could be a variation in "heat demand" in different rooms, as well as within a single room. It is important to generate the necessary heat in small, independent devices rather than at one central source in order to be able to react to local specifications. To operate several small generators a versatile and efficient system to deploy electric energy is needed (as shown in fig. 1).

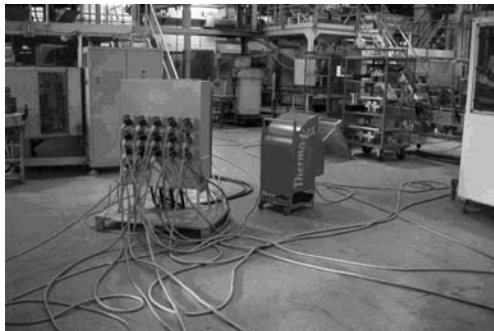


Fig. 1 Distribution of Energy



Fig. 2 ThermoNox heater with 18.75 kW (0.75 kW for the fan)

The heater is equipped with an axial fan. Air is sucked into the unit through the bottom sides and fed through the damper registers. Warm air leaves the heater unit horizontally at the top. The temperature of the circulated air is controlled by integrated thermostats.

- The heater is fitted with two wheels and a handle which makes it easy to reposition it during the heating period.
- Depending on nature and amount of material in the room one heater is necessary per each 100 – 500 m³.

A typical heating curve is shown in Fig. 3. The graph represents a time span of 48 hours, in which the first 24 hrs were needed in the heating phase. Sharp variations in the graph represent repositioning of heaters (sensors were not repositioned). The second 24 hours are the maintaining phase. At the far right of the graph heaters were switched off at the beginning of the third (cooling) phase.

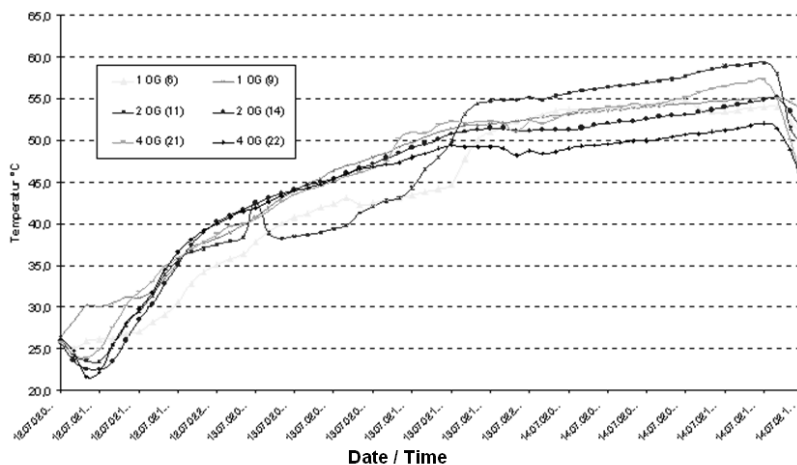


Fig. 3 Temperature curves

Maintaining temperature: During the maintaining phase it is made sure that the target (kill) temperature is reached in all parts of the treatment area and maintained throughout the duration of the treatment. The longer the temperature can be maintained in that phase better heat dissipation is guaranteed a higher treatment efficacy can be achieved. During this phase heaters cut back automatically to 50% capacity and alternate on and off, because only heat loss has to be compensated.

Cooling phase: Towards the end of the maintaining phase doors and windows are opened, the heaters are switched off but the axial fans are left running. The effect is a "reversed" heat transmission supporting the cooling of building and installations.

Advantages of ThermoNox treatments:

- Absolutely non-toxic pest control in sensitive areas
- No residue, odourless
- Effective against adults, larvae and even eggs
- No resistance in insects possible against heat
- Deep penetration of cracks and crevices and otherwise inaccessible areas
- A secure procedure because of the slow-rising temperature and the maintenance of steady 55 – 60 °C
- Discreet treatment, independent from outside temperatures (year-round method)

Limitations:

- As all treatment methods, the ThermoNox-System has certain limitations and drawbacks. Some of these are:
- Not applicable in locations without a sufficient electrical power source
- Temperature sensitive raw material or products
- Filled containers, silos and plants inside the treated area (heat does not reach infestation > insects survive > recalls)
- Special floor constructions (materials with very different thermal coefficient of extension)
- Big, empty concrete silos, high concrete staircases, humid ground-floors
- Outer walls with outlying isolation
- Insects escaping to an area not heated and survive (barriers!)
- ThermoNox requires trained and experienced application technicians (just like modern precision fumigations)
- Thermal treatments "as such" do not have a lasting effect, therefore they have to be carefully planned and executed – the aim is eradication (no survivors).

The ThermoNox System is not a panacea but very close

Literature

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12 - Residues of Biocides and Pesticides in Stored Product Protection (SPP) Available active substances, specific problems

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Abstract

To meet the high quality criteria for food, very effective methods are needed to control insects and other pests during storage. Chemical SPP products are widely used for this purpose. However, the number of active substances which may legally be used in storage protection is very limited. High efficacy of the substances is often linked with high toxicity also towards humans. This gives rise to concerns for the safety of workers and/or consumers. A large variety of food and food products comes in contact with SPP products and consumers may be exposed to these chemicals via residues in food. Storage protection is an area that falls both under the biocide and the pesticide legislation. An overview is given on available active substances (biocides and pesticides) and some specific residue problems including the current state of discussion in the EU.