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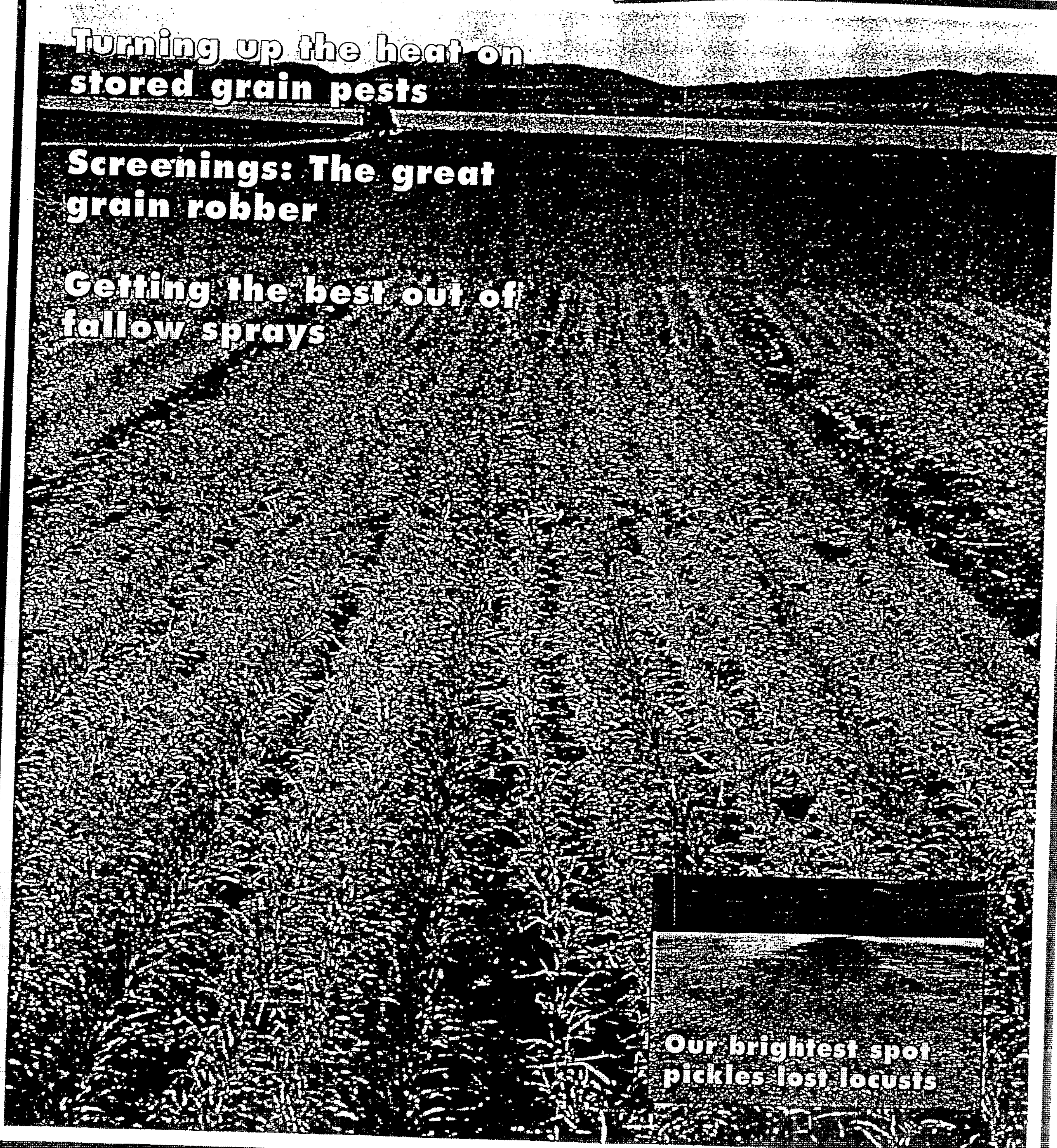

Turning up the heat on stored grain pests

By Rashid Qaisrani, CSIRO Stored Grain Research Laboratory

The use of high temperatures is one of the promising methods to provide a rapid, non-chemical alternative to fumigation for control of stored grain insects. Increasing market preference for residue-free grain, development of high level insect resistance to phosphine, and the pending phase out of methyl bromide (MeBr), currently used for rapid disinfestation of grain, are all reasons supporting the need for research and development in heating technology.

The Stored Grain Research Laboratory (SGRL) is currently evaluating in-bin and spouted-bed disinfestation systems for on-farm use. These methods open up a whole new era of heat disinfestation, will help farmers disinfest their grain without being exposed to toxic chemicals, and they disinfest grain very quickly.

Early use of heat disinfestation

The concept of heating grain to control insect pests is not new*. During WWI, stored wheat was heated to 58–60°C for at least three minutes as an insect control strategy. A continuous-flow machine was used and wheat was heated as it circulated over steam-filled pipes. The average residence time within the machine was 15 minutes at an average throughput of 28 tonnes per hour.

Chemical control: Does heat have a role?

The Australian grain industry remains largely dependent on chemical control of insect pests and needs to develop alternative methods of grain preservation and pest control. More than 80 per cent of the Australian cereal, oilseeds and pulse crop is treated with the fumigant phosphine to control infestations. A declining proportion is treated with residual chemical protectants.

Currently MeBr is used in Australia and overseas for rapid disinfestation and is used extensively at port facilities for rapid disinfestation and quarantine purposes. But what technology will be available for rapid grain disinfestation when MeBr is phased out in 2005?

Heat disinfestation — in one or more forms — may be used to control insect pests within the next 10 years, particularly in an integrated approach to grain protection.

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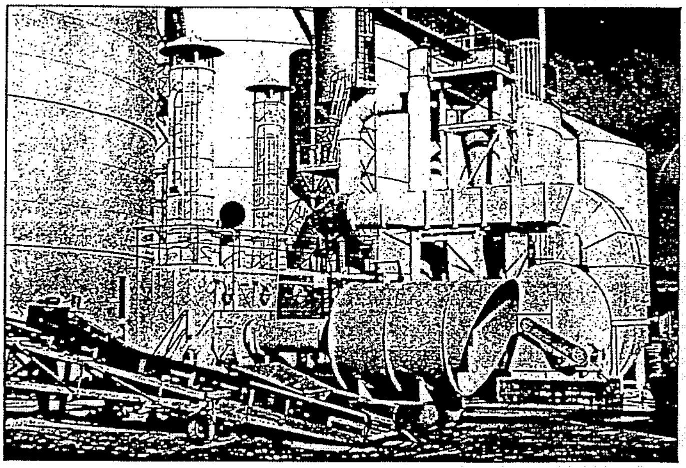
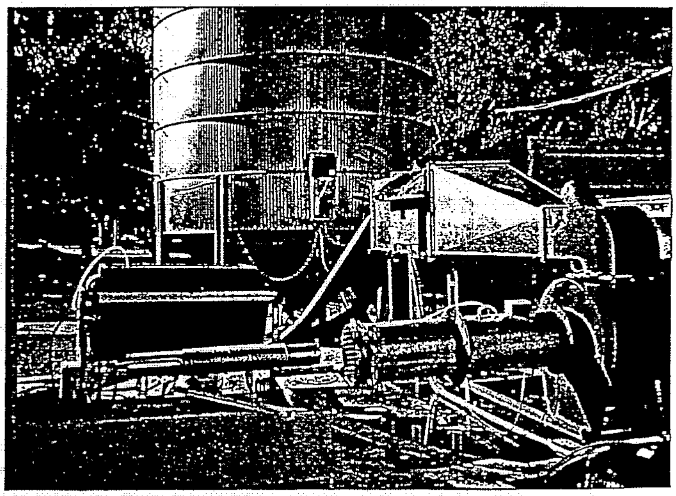


This commercial fluidised-bed disinfestation system was built and evaluated by CSIRO at Dunolly, Victoria



An in-bed disinfestation system has also been evaluated by CSIRO.

HEAT DISINFESTATION SYSTEMS

An ideal disinfestation system for either commercial or on-farm use would be:

- Comparatively rapid, cost effective, safe and easy to use;
- One that maintains or improves grain quality with minimum adverse impact on the environment; and,
- One that is flexible, versatile and suitable for individual grain lots.

Heat technology is continually being improved, and SGRL has taken all these characteristics into account in its current work on disinfestation systems with the objective to achieve a balance between all three characteristics.

There are a number of factors that influence the effectiveness of heat treatment. Inlet air temperature, exposure time, insect species and their age structure, initial grain temperature and moisture content, and type of grain, all have an effect. Stored grain pests are killed within seconds when exposed to temperatures above 65°C. The exposure time increases as grain temperature decreases, taking a few hours at 50°C and days at 45°C.

Laboratory studies have shown that stored product insects tend to succumb to heat more rapidly in dry grain. In practice, the heat dosage applied varies with circumstances, ranging from a few seconds at 65°C to days at 45°C.

Fluidised-bed heat disinfestation

Hot-air convection heating in a fluidised bed was first studied in Australia in 1978. The disinfestation process involved rapid heating followed by rapid cooling to safe handling and storage temperatures. In a fluidised bed, the grain passes at a predetermined flow rate across a sloping metal plate perforated with holes of specified diameter and orientation. During flow of grain across the fluidised bed, the grain is heated to a specific temperature that kills all developmental insect stages, including the larval and pupal stages of those species that develop inside grain kernels.

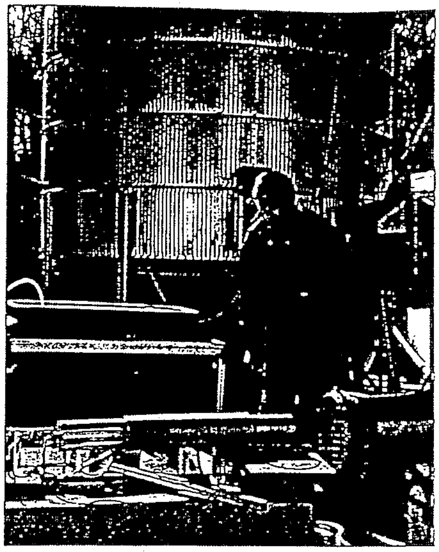
The lesser grain borer (*Rhyzopertha dominica*) and grain weevils (*Sitophilus* species) are the most heat-tolerant species of stored grain pests. Studies showed that grain infested with these insect species flowing at 360–500 kg per hour at a depth of 100–250 mm across a fluidised bed, with an inlet air temperature of 80–90°C, was completely disinfested within three minutes.

The first commercial unit built and evaluated at Dunolly in Victoria in the 1980s had a capacity of 50 tonnes per hour, an air inlet temperature of 100°C, and achieved a maximum grain temperature of 65°C using a mean residence time of two minutes. Complete kill of lesser grain borer was obtained at higher grain flow rates of up to 200 tonnes per hour, when grain temperature was raised to 65–70°C with a grain flow rate of between 2.1 and 2.4 kg per second per square metre, and mean grain residence time of two to 4.5 minutes.

In-bin heat disinfestation

In-bin heating of grain is a technology that shows promise for use in small capacity (up to 50 tonnes), partially sealed farm bins (Figure 1). It is currently being investigated at the SGRL with funding from the Grains Research Development Corporation (GRDC).

The in-bin process involves slowly heating the infested bulk by moving a heating front through the grain. Ambient air is heated to the required temperature and fan-forced into the grain. The heating front is progressively moved through the bulk by continuing to force ambient air into the unit, and the rate of movement is controlled by the air flow rate. The concept is similar to that used for cooling of grain using aeration, where cooling fronts are established and then gradually moved through the bulk.



A steam disinfestation generator supplies super-heated steam into the hot air stream improving the performance of the in-bin disinfestation system.

There is a workable window between heat dosages that kill insect pests and those that cause significant damage to product quality. The SGRL is evaluating suitable heat disinfestation systems and heating/cooling regimes that achieve effective control of the more heat-tolerant insect species, without affecting grain, processing or end-product quality. Grain temperatures in the range of 48–50°C are being evaluated.

The system being evaluated comprises a high-capacity fan, a heating unit with variable output, and four perforated ducts inside the silo. Heated air can either be forced up through the ducts located in the hopper bottom, or sucked down from a single duct at the top of the silo.

The addition of a steam generator improves the performance of the system. Typically, hot air with higher relative humidity raises grain temperature without excessive drying, and improves performance by reducing loss of energy through evaporative cooling. The system includes a complementary cooling unit that prevents prolonged heating of treated grain. The in-bin system can also be easily modified for ambient aeration and in-bin drying of grain.

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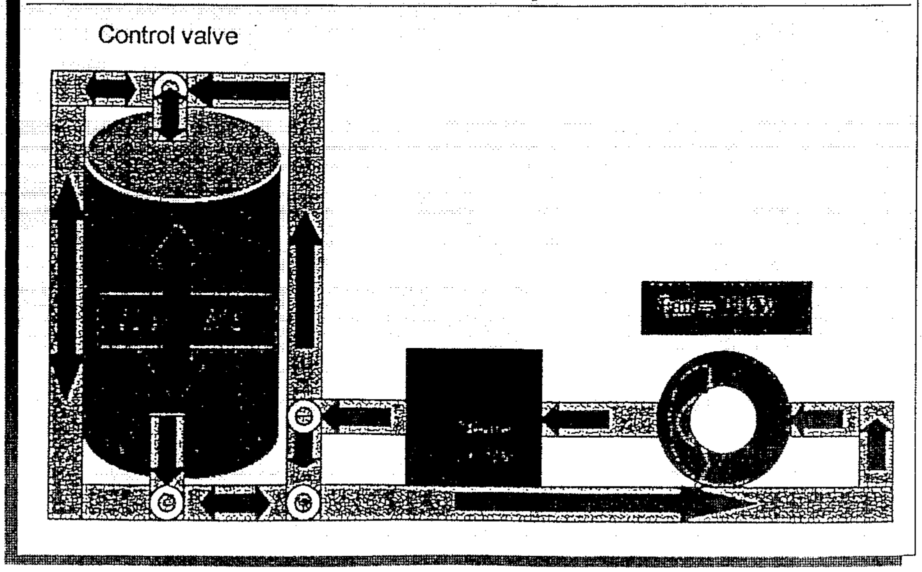
FIGURE 1: An in-bin heat disinfestation system



Spouted-bed heat disinfestation

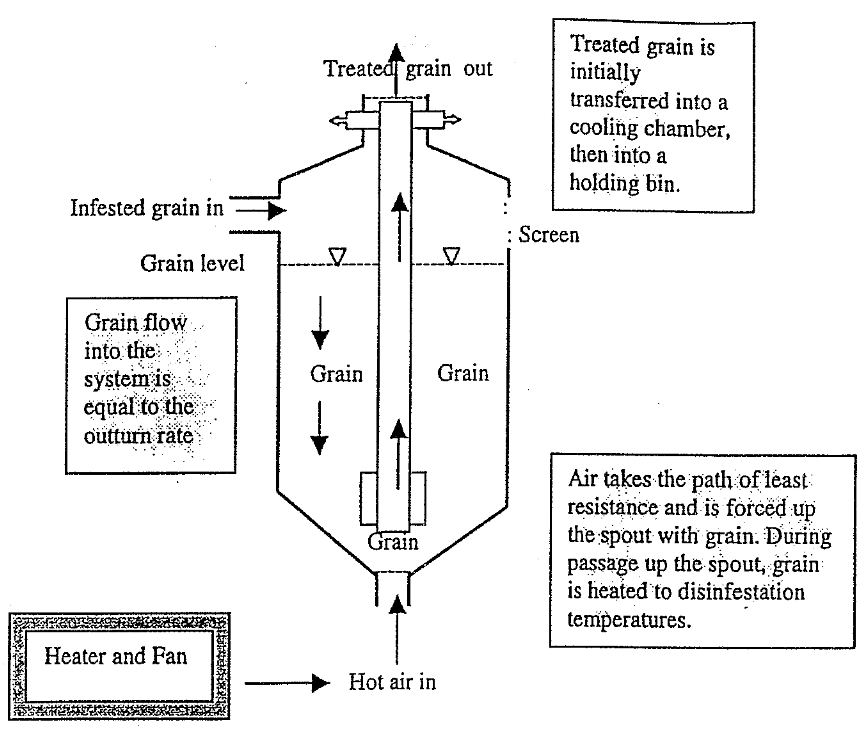
The spouted–bed unit is a modified form of the fluidised-bed heat disinfestation system (Figure 2). In a spouted bed, air enters at high velocity through a nozzle located at the conical bottom of the bed. A high velocity air stream causes grain to spout above the air inlet. As infested grain is percolated up the spout, it is heated to temperatures that disinfest the grain.

Treated grain moves from the spouted-bed into a cooling chamber where grain temperature is rapidly reduced to levels that minimise quality loss. Following cooling, the grain is transferred to a holding bin, or turned backed into storage.

A spouted-bed heat disinfestation system capable of heat treating grain at 10 tonnes per hour is currently under investigation at the SGRL, again with funding from GRDC. This system has potential use on-farm, being more rapid than an in-bin heat disinfestation unit. The spouted bed can also be used to disinfest or dry larger grain such as corn. It has no moving parts, and its mode of operation is easier and occupies less space than a fluidised bed.

Preliminary results show that the cost of disinfesting grain by a spouted bed is less than that using an in-bin heat disinfestation system. The flexibility of being able to use both the in-bin and spouted-bed heat disinfestation units as grain dryers, and the in-bin unit for ambient aeration, will off-set capital costs associated with these systems.

FIGURE 2: A spouted-bed disinfestation unit



◁ 3...TURNING UP THE HEAT

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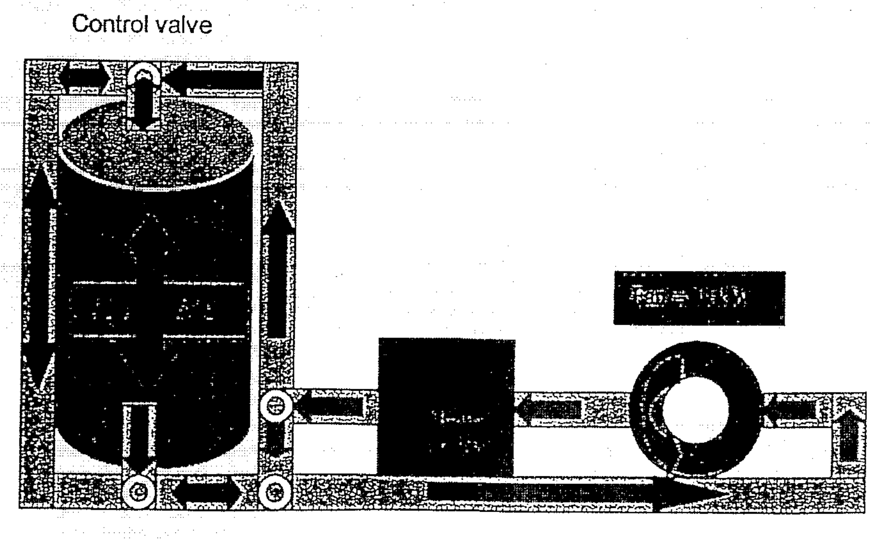

TABLE 1: Operational (energy) costs of heat disinfestation using different techniques

Heat disinfestation system	Energy cost of disinfestation ($/t)
In-bin (45 tonne partially-sealed steel silo)	2.10
Fluidised bed (30 t/h)	1.43
Spouted bed (10 t/h)	1.30

COST OF HEAT DISINFESTATION

The spouted bed appears to be the most economical method of heat treating grain. Because the different insect disinfestation systems are at a prototype stage, it is difficult to determine a 'real' capital cost. But the capital cost of a spouted-bed unit is likely to be substantially lower than an in-bin or fluidised-bed system. Using the heater and fan either for in-bin or for a spouted-bed disinfestation system can also reduce the capital cost of a spouted bed. The unit may also be used as a dryer.

Comparative operational (energy) costs of different heat disinfestation systems are shown in Table 1. The low overall cost of installing and operating a spouted-bed unit, together with its greater flexibility and versatility, makes this system well suited to on-farm use. Further development and field experimentation are required before either spouted-bed or in-bin systems are presented as ready-to-go methods of disinfestation.

POTENTIAL HEAT DAMAGE

Susceptibility of grain to heat damage varies considerably, and is influenced by grain type and moisture content at the time of heat treatment. Both physical and biochemical damage of the grain can result from rapid heating. Rapid cooling immediately following heat treatment has been shown to minimise loss in grain and end-product quality.

Dry grain is more tolerant of the effects of rapid heating. The majority of grain harvested and delivered into central storage in Australia is received at moisture contents below 12.5 per cent. The dryness of grain at the time of harvest makes an in-line rapid disinfestation technique, such as spouted-bed or fluidised-bed technology, feasible options for the Australian grain industry.

Heat damage can also occur with a rapid drying process, where heated air is fan forced through a treatment chamber to remove grain moisture. Damage from poorly-controlled grain drying is a well-recognised problem in the grain industry.

Loss of processing quality in malting barley is one example, where inappropriate inlet air temperature or exposure time can substantially affect viability and vigour of seed. Grains are also liable to crack when subjected to rapid drying, increasing the risk of deterioration when stored.

Maintenance of grain quality during drying is essential. It is important that the drying and heat disinfestation processes are understood and undertaken with care.

Further research

The SGRL, with growers' support via GRDC, is continuing to research in-bin and spouted-bed heat disinfestation systems.

The research phase needs to be followed by the extension of the results to growers through field trials, on-farm demonstrations and actively involving grain growers in heating technology.

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*A full account of the early development of heat disinfestation systems in Australia can be found in *Weevils in wheat and storage of grain in bags — a record of Australian experience during the war period (1915 to 1919)* by D.C. Winterbottom.