International Conference of Agricultural Engineering
AgEng 2014 Zurich 6–10 July

Ref: C0372

Tractor cab to protect the operator from hazardous substances in spray application

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Abstract

Crop protection is mostly carried out spraying active chemical agents with potential impact on the health of environment, operator and consumer. Recently the European Commission played an important role in the protection of the operator with respect to the pesticide contamination during spray application. An active protection offered by tractor cab is a new requirement when the machine is used in crop protection. The solution to be adopted by the tractor manufacturers is the fitment of filtered and pressurized cabs.
The subject is quite recent but a dedicated standard has been developed, the EN 15695:2009, to define the testing procedure to evaluate the performance of these cabs. However some lacks of information are evident in the standard application and only few prototypes of filtered cabs for self-propelled sprayers are nowadays on the market.
The goal of the work has been to design and test in field a filtered and pressurized cab prototype fitted on a narrow-track tractor for orchard and vineyard. Two years of activity were carried out. Starting from a commercial cab already existing, the cab was re-designed and fitted on the tractor modifying completely the roof in order to locate the new type of active carbon filters required by the European standard. Then the tractor-cab platform was completely sealed in order to reach the required pressure level into the cab. Once the cab was ready and the standard requirements were fulfilled, the tractor was tested in orchard and vineyard for one year at the experimental farm of the University of Bologna.
The results of the tests showed a positive performance of the prototype but highlighted the need to improve the standardized procedure with additional points on the correct use and maintenance of the cab during the normal operation in field. A crucial issue was to define the methodology for the evaluation of the performance of the active carbon filters during the use of the tractor in pesticide application in order to assess the field durability of filters.

Keywords: Pesticide, Crop protection, Sprayer, Tractor, operator contamination.

1 Introduction

Pesticides for crop protection are frequently distributed using self-propelled or tractor driven boom and orchard sprayers. In the years the evolution of sprayers showed new developments introducing technological systems to reduce the risk of contamination both for the environment and the operator involved in the spraying task.
Modern sprayers are normally air-assisted machines; many studies have demonstrated that air-assistance improved the spray application and, combined to spray localisation and low-drift and air-induction nozzles, contributed to reduce environmental drift (Ade and Rondelli, 2007; Pezzi and Rondelli, 2000; Ade et al., 2000; Taylor and Andersen, 1997). Nowadays at the European level new requirements for machinery designed for plant protection products (PPP) application are foreseen because the use of PPP is defined as posing threats both to human health and the environment (European Commission, EC, Directive 2009/127). The directive recognises that the design, construction and maintenance of machinery for PPP

application play a significant role in reducing the adverse effects of PPP on human health and the environment.

Workers are subject to a high risk of pesticide dermal exposure during mixing, loading and maintenance tasks (Dubelman et al., 1982, Landers, 2003, Balsari et al., 2006). Knapsack sprayers demonstrated to produce higher operator dermal exposure levels than either tractor mounted or drawn sprayers (Abbot et al., 1987).

Engineering controls and personal protective equipment (PPE) are available to reduce contamination hazards for the operator (Landers and Hill, 1996, Coffman et al., 2009).

PPE represents the primary method to lower the worker exposure to pesticides. A survey of 702 certified pesticide applicators in three US States assessed a high level of PPE use and chemical-resistance gloves showed the highest level of compliance (Coffmann et al, 2009). The authors reported that the majority of respondents did not wear less PPE because they used engineering controls; however some of them modified their PPE choices when tractors with enclosed cabs were used. The survey pointed out that more than 50% of the respondents adopted engineering devices as enclosed tractors, low-drift nozzles and hand wash supply. Additional controls were loading devices, such as closed transfer systems and induction bowls, and hydraulic folding boom. Landers et al in 2000 reported a survey showing a lower use of engineering controls; indeed closed systems, induction systems, tractor cabs with carbon filtration and tank rinsing systems were found in no more than 25% of the farms visited in ten US states.

In Italy the results of an inquiry carried out by Balsari and Oggero in 2002 showed that in the orchard areas located in the north west one third of tractors used in pesticide crop protection was without enclosed cabs and only 70% of the pesticide applicators declared to use protective gloves, masks and clothes while 10% of them did not wear PPE.

Enclosed cabs demonstrated to reduce operator dermal exposure when compared to open-air tractors (Abbott et al., 1987). In the United States since 1997 the American Society of Agricultural Engineers (ASAE) published definitions, testing procedure and performance criteria related to enclosed cabs for pesticide applications incorporating a respiratory protection (ASAE S525:1997). Part 1 of the standard referred to the overall performance of the agricultural cabs, while part 2 provided test procedure under laboratory conditions and performance criteria for pesticide vapour filters. The filter defined as an air purifying device or element to remove solid or liquid aerosols, pesticide particle diameters typically from 3.0 μm or greater, was a part of the pressurization system providing fresh air for the cab. All air entering the cab had to pass through the air filter device. The aim of the device was reducing the level of pesticides in the air flow passing through the filter to at least 1/50 of the level outside the cab, corresponding in terms of filtering performance to the level of reduction specified for full face respirators. A study was carried out to examine the potential efficacy of air-filtered cabs in reducing operator exposure (Kline et al., 2003). Tractors and commercial spraying equipment were investigated to evaluate the level of pesticides and herbicides in samples taken from various interior and exterior locations. Seats and steering wheels were recognised as surfaces contaminated with more pesticides than other hard surface areas. The Authors pointed out also that pesticide residues on the air outlets of the enclosed cabs often included more compounds and at higher levels than samples from the air inlets. It was suggested that the air filter carbon beds used, once saturated, might release compounds back into the tractor cab environment. The weak point in the standard was the lack of information from the cab or filter manufacturers on the carbon filter replacement schedules. Other research activities proposed a stationary method for screening the environmental cab for aerosol penetration into the tractor cab by using a laser particle counter to compare the particle number concentration inside and outside the cab (Moyer et al., 2005). A review of the basis of the ASAE standard S525 pointed out that the cab manufacturer had to develop a quality control plan for the manufacturing process and to provide the end users with a maintenance plan to ensure that the cab performance remains adequate in the time (Heitbrink et al., 1998). At this end the maintenance programme preferably had to involve periodic verification of the enclosed cab. Other limitation of the standard were considered the particle size addressed, larger than 3 μm, and the lack of specifications on the degradation of the filter performance with time.

A new American national standard for tractors and self-propelled machinery for agriculture has been approved in 2013. It is the ANSI/ASABE S613-2.1 for cab and Heating, Ventilation

and Air-conditioning System (HVAC) and the S613-3 for filters fitted for environmental cab HVAC systems. The aim of the new standard is to design principles that define a robust cab and HVAC system used in contaminated environments as part of an occupational health and safety management system. The interesting new approach with respect to the previous ASAE standard is the introduction of the estimation of the service life of the air filter device so as to provide a recommendation to the machine user.
Quite recently in the European countries new rules have been enforced requiring air filtering systems fitted to the enclosed cabs of self-propelled sprayers and tractors, when used in pesticide crop protection, to provide respiratory protection for the worker against dusts, aerosols and vapours (European Union, EU, Directive 52, 2010 integrating the Directive 37, 2003). The European standard EN 15695:2009 specifies different categories of cabs, the relevant requirements and the test procedures to limit the exposure of the driver to hazardous substances when inside the cab. It also specifies the information to be provided by the tractor or self-propelled sprayer manufacturer. However the standard does not cover the exposure linked to fumigants, the actual cab performance in the field applications and the field durability of filters. Criteria are provided in part 1 of the EN 15695 standard for testing the air delivery and filtration system and the housing of the filter of the cab. The performance is tested by determining the leakages of the air delivery and filtration system installed in the cab during the “blind filter test” or verifying the isolation effectiveness of air delivery and filtration system installed in the cab by measuring the aerosol concentrations with an optical counter inside and outside the cab.
Part 2 of the EN standard specifies filters requirements and test procedures. Effectiveness of the filters against vapour is checked according to cyclohexane method during 70 minutes. The standard reports also that information on the intended filter use, installation, service, maintenance and replacement should be provided to the end users but no specific provisions are clearly reported with respect to these aspects.
The goal of the work was to design and test in field a filtered and pressurized cab prototype fitted on a narrow-track tractor for orchard and vineyard. Two years of activity were carried out to develop and test in field the cab performance.

2 Materials and methods

2.1 Tested tractor and field test

The tractor selected was a commercial model of narrow-track tractor for orchard and vineyard fitted with a Roll Over Protective Structure cabin. The enclosed cab was designed so as to modify and update an already existing commercial cab to the requirement of the European directive EU/52/2010 according to category 4 of the EN 15695-1:2009, providing protection against dusts, aerosols and vapours. The roof cab was completely redesigned so as to locate the filter type to correspond to the standard requirements. The air delivery system inside the cab was designed with four adjustable air outlets, an air recirculation device and a blower speed-setting governor. A blower and an air-conditioning device integrated on the roof cab completed the system. Two filters were installed at the roof sides. The filters were tested according to the category 4 of the EN 15695-2:2009 by the filter manufacturer.
A smoke test (Figure 1) was performed during the cab development so as to study the leakage due to the connection between the cab and the tractor chassis and in the passage points of tubes and cables into the cab. This test allowed removing possible leakages, which could decrease the internal cab pressure.
A dust test was then performed (Figure 1) to measure the leakage at the filters housing. Dust was sucked through the possible openings between the filter and its house. At the end of the test the filters were removed and dust in the filter housing was evaluated. One year of tests were carried out to develop the filtered cab prototype and at the end of the first year a pressure indicator was fitted on the cab, as foreseen by the standard.
In the second year the tractor was tested in orchard with a trailed sprayer in pesticide application. The experimental farm of the University of Bologna was selected to study the performance of the cab during the 2012 spring-summer season. To check the cab performance

laboratory tests according to the provisions of the standard EN 15695-1:2009 were scheduled every 15 days.

Figure 1: Smoke and dust tests.

2.2 Laboratory tests

The EN 15695:2009 is divided into two parts: the first part is dedicated to the Cab requirements; instead the second one refers to the filter requirements. The EN 15695-1:2009 defines four cab categories starting from category 1 not providing a protection against the hazardous substances, till the category 4 cab designed to provide a protection against dusts, aerosols and vapours. Cab categories providing protection need corresponding filter categories tested according to the EN 15695-2:2009/AC:2011.
The cab standard requires for the 4 level of operator protection a minimum positive differential pressure within the cab of 20 Pa. This pressure has to be measured according to the ISO 14269-5:1997. The air delivery system installed in the cab 4 has to provide at least 30 m^3/h of filtered air.
The flow of unfiltered air into the cab was based on the measure of the leakages of the filter housing, as foreseen in the Annex B of the standard. To carry out the evaluation of the air leakages a dedicated device, defined in the standard as Test hood, was designed in order to cover the inlet of the air delivery and filtration system.

Figure 2: Blind filter.

This device allowed to better measure the airflow throughout the filter. Firstly the test was performed so as to measure the airflow passing through the filter; then the airflow was measured with the blind filter (Figure 2) to define the filter housing leakages. The ratio between the second measure and the first one has to be less than 2%.

2.3 Measurement equipment

The differential pressure and airflow data, to evaluate the performance of the cab and air ventilation system, were measured with a Delta-Ohm’s data logger. The data logger was connected with a vane probe, to measure the airflow velocity, and a pressure probe. The characteristics of the probes are shown in Table 1. The airflow rate was calculated on the basis of the air velocity measured with the vane probe.

Table 1: Measurement equipment.

Parameter	Device make	Model	Measurement range
Differential pressure	Delta OHM	DO 9847 (Data logger)	
		PP473 S1 (Sensor)	+/- 1000 Pa
Airflow rate	Delta OHM	DO 9847 (Data logger)	
		AP472 S2 (Sensor)	0.5 – 20 m/s
		AP472 S4 (Sensor)	0.6 – 50 m/s

3 Results and discussions

A new design of filter, complying with the category 4 of the standard EN 15695-2, was fitted on the cab prototype. In order to meet the standard provisions the new filter was made larger than the standard filter (Figure 3). The roof was redesigned so as to locate a filter housing greater than the normal type fitted in the previous commercial version of the tractor cab.
The smoke test pointed out some leakages and the following cab updating allowed increasing the performance of the pressurization system. The dust test highlighted the need to add a perimeter seal on the filter housing and to provide a better locking system of the filters.

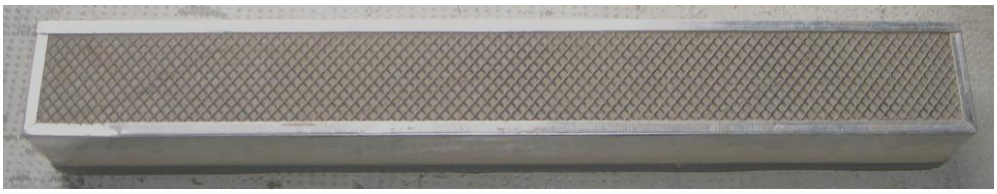

Figure 3: Category 4 filter fitted on the cab prototype.

The point 5.4.2 of the EN 15695-1 standard was fulfilled fitting a dedicated differential sensor pressure on the right pillar of the cab (Figure 4). This device measures the pressure inside the cab and when the pressure value is lower than the one required an audible alarm is activated.
During the year of field test with the tractor used in orchard and vineyard at the experimental farm of the University of Bologna, laboratory tests were carried out every two weeks to check the cab performance maintenance. The differential pressure and the leakage of the filter housing were carefully evaluated. Some adjustments were necessary to maintain the initial performance due to leakage of the filter housing. Modification in the differential pressure was not detected.
In the field tests the tractor operator did not experienced the smell of pesticides.

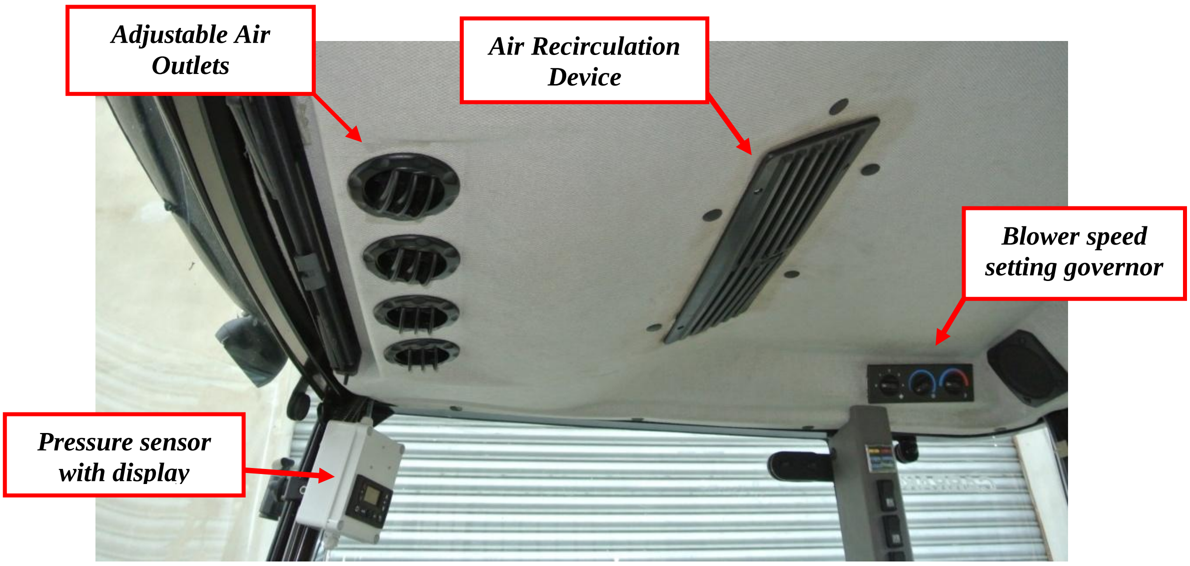

Figure 4: Cab inner.

4 Conclusions

An air filtering systems fitted to the enclosed cab of a narrow-track tractor for orchard and vineyard to provide respiratory protection to the operator against dusts, aerosols and vapours was designed and tested in field. The designed cab was a 4 category cab according to the EN 15695:2009 standard. During the tests lacks of information were evidenced in the reference standard to support the tractor operator in the cab and filter maintenance.

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