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The performance of UK purchased side lever knapsack sprayers when subjected to the test methods proposed by ISO CD 19932-1

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The performance of UK purchased side lever knapsack sprayers when subjected to the test methods proposed by ISO CD 19932-1

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Seven side lever knapsack sprayers were subjected to test methods of a proposed International Standard that should be finalised by Working Group 5 on 19/20 September 2000. Most test methods were found to be relevant and could be practically implemented. However, that proposed for the volumetric measurement of internal residual liquids was found to be too variable; it was influenced by the pumping side-lever's juxtaposition to the pump whilst being used on an operator's back. However, the performance of these sprayers in other tests has indicated that they are capable of meeting most proposed limits. Indeed, some limits such as those for leakage and stability, may be made more demanding but some, such as impact and strap strength may need to be reconsidered. None of the individual machines purchased from one UK dealer in August 2000 were found capable of passing all of the proposed performance limits but neither did any fail them all. Earlier Health and Safety Executive (HSE) requests for less leakage and lower external surface deposits on this type of sprayer have been introduced to their specification.

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BACKGROUND

The possibility for knapsack sprayer operators to be exposed to pesticides, during normal commercial practice, has caused justifiable concerns. Regulatory Bodies and equipment manufacturers have therefore encouraged the development of an International Standard that will form a basis by which key safety features may be judged. Test Methods for the Standard are now awaiting international comment whilst Performance Limits will be formally proposed on September 19/20 2000.

Thornhill and Taylor published data in 1998 for knapsack sprayer performance but used Test Methods as prescribed by British Standard 7411:1991 and evaluated machines, now dated, that manufacturers have claimed are now improved. All Performance Limits, they concluded, were capable of being met but no single type of side lever knapsack sprayer could pass them all.

This study was made:

to establish if the proposed, modified Performance Limits for the new IS Test Methods were appropriate for acceptance by the UK Enforcement Body; the Health and Safety Executive

to offer advice, from a sound rational basis, for improvements through the BS AGE 15 committee to the next IS Working Group meeting on September 19/20 2000.

THE MACHINES

The seven side lever knapsack sprayers selected were those that would be purchased in the UK: dominating all existing sales. Whilst the original contract specification was for only six types to be used, it was considered prudent to include a seventh since this particular model is popular in one local market. All machines had a rated 15 litre capacity, were purchased from one Dealer [Thrapstones of Kettering] and delivered to IPARC. Retail prices were all very similar. Machines were removed from their boxes and given an identity code [Table 1].

Table 1

NOTE: Table 1 has been removed as it identifies individual manufacturers. The seven knapsack sprayers were numbered from HSE1 to HSE7. In due course the results of this study will be passed to the manufacturers concerned with their own machines identified. They will not be able to identify other models.

Comments on ease of assembly and likely serviceability:
A] HSE 2 was rated as very easy to assemble but demanded, however, a spanner that was not supplied.
B] Many had straps fitted but some [such as HSE 4 and 6] did not and were found to be "not easy".
C] Most machines had appropriate nozzles supplied but one [HSE 6] only offered a variable output cone.
D] In general, fitting the lever handle was easy and all could be used for left or right operation. HSE 7 took the longest time to fit the lever correctly and was rated "very difficult" but its splined shaft could suit several angles for maximum operator comfort; an ergonomic benefit also being shared by HSE 3.
E] Control valves that ensure minimal line pressures need to be attained before spraying and maximum pressures can not be exceeded [Spray Management Valves] were used with HSE 1 and 7 but also supplied with HSE 5. Pressure selection valves are an integral part of HSE 1 and HSE 2 but are situated within the tank. HSE 7 also had a pressure selector valve which is an integral part of the machine but is externally adjusted.
F] One machine [HSE 1] was supplied without a trigger lance assembly and had straps wrongly assembled. In one instance [HSE 5] hot water was required to soften the spray line before it could be fastened to the pump hose coupling.
G] All had instruction books. Some contained irrelevant information and some were not easy to follow due to a confused layout.

TEST METHODS

Test Methods were followed as precisely as possible but some changes were found to be needed. We have noted where difficulties occurred and suggest, where appropriate, a modified alternative protocol. In addition, the sequence of test order was also changed. In normal practice, it is required that test operators should start with durability [5.2.1], cut-off valve reliability [5.2.2], then strap tests [5.2.3] before making volumetric measurements or other observations. The purpose of this study, however, was to establish the "best commercial practice" that is attainable today in the UK with machines in their original supplied condition. It will be manufacturers that will have the responsibility to demonstrate that they can meet the rigors of normal usage [the Tests noted above] and do so without subsequent detriment to performance in other tests. We decided to conduct the, potentially destructive, Strap and Impact Tests last.

EXTERNAL SURFACE DEPOSIT: IS TEST 5.2.4

The sprayer has to be dry. The lid or the air pump, respectively, is to be removed and an inverted cone fitted into the filling orifice.
A volume of test liquid, that equates to the sprayer's nominal capacity, shall be poured at a rate of 250 mls/s into the inverted cone such that the cone fills and then simulates overfilling. The cone shall be removed and the sprayer drained for 1 minute.

Comments: Two 10 litre buckets which each contained 7.5 litres of test liquid were used and poured at an even rate for 60 seconds from a fixed height. One cone that would fit all sprayers [despite them all having a filling orifice diameter of ca. 100 mm] was difficult to find due, in some instances, to obstructions within the tank. The test was, therefore, modified by enclosing the filter basket within a polythene bag fitted such that it followed the filter's internal contours. The poured liquid struck the polythene and was reflected out.

We noted that the new machines were coated with a silicone [?] mould release agent that displaced surface liquid. We observed in later tests that this surface coating lost some of these repelling characteristics.

The proposed Performance limit suggested by ISO/TC 23/SC 6 WG 5 is <100 mls. Only one machine [HSE 7] failed this test to suggest the proposed limit represents good commercial attainment [Table 2]. It is likely that this knapsack sprayer designed with both a central filling orifice and with a complex structure under the tank, would contribute to high external surface values.

Table 2
External surface deposits; mls of spray solution

HSE 1	65
HSE 2	62
HSE 3	55
HSE 4	68
HSE 5	59
HSE 6	39
HSE 7	208

Note: Test Method was slightly changed. We believe that liquid poured into the filter basket, should be at a fixed, specified height and may be preferred to the raised surface of an inverted cone, to simulate over filling with more reproducible accuracy. In this test, the BS 741 rate of 0.22 litres second was used. Although not proven, it is considered that all machines should be preconditioned to remove the mould release agent. Suggest they are washed in a non-ionic surfactant aqueous solution of 0.5%. The Performance Limit for 15 litre knapsacks could be reduced to a threshold of < 70 mls.

INTERNAL RESIDUES: IS TEST 5.2.5

The sprayer shall be filled with water or test liquid, carried in the recommended operating position but with hose and lance in horizontal position.
The cut-off valve shall be closed immediately air starts to come out of the nozzle.

Comments: Some side lever knapsack sprayers have an off set filling orifice to one side of the tank and, within, a piston pump fitted on the other side. Lever operation can be either side. It was noted that the side on which the lever is operated during the compression stroke [downwards] *when carried* lowered the tank - with the residual liquid - on that side too. The liquid may flow away from the sump or to it. Thus it is possible with the same machine to produce contrasting values. Some designs that were expected to readily pass, have failed when following this protocol. This bias was of a magnitude great enough to dominate that which is attributed to pump type; the proposed limit of 500 mls being suggested for those with diaphragms [HSE 1] whilst for piston pumped it is 250 mls.

Only one machine [HSE 7] passed the Internal Residue Test due, we believe, due to its central pump and sump [Table 3]. It is suggested that the Test Method is reworded such that the sprayer is mounted on a solid horizontal surface rather than the operator's back.

Table 3
Internal residues; mls of spray solution

HSE 1	590
HSE 2	289
HSE 3	337
HSE 4	815
HSE 5	559
HSE 6	452
HSE 7	107

Note: Test Method may have to be modified to *"….…..test liquid, mounted on a stable bench* [to average out good/indifferent operator practice] *at normal operating height but with hose and lance in horizontal position and nozzle fitted. The cut-off valve shall be closed immediately air starts to come out of nozzle. Leave trigger valve open until pressure dissipates"*
Tests will need to be repeated to establish likely compliance with a proposed Performance Limit. However, it is suggested to not have dual limits but use < 500 ml threshold for all side lever knapsack sprayers. There are at least two concerns. Environmental, operator safety considerations are paramount whilst some hybrid piston/diaphragm models may defy easy categorisation in future tests.

FILLING RATE: IS TEST 5.2.7

The dry sprayer is to be filled at a pouring rate of 10 litres/6 s in case of lever operated …..…sprayers with an unprofiled bucket up to its nominal capacity.

Comments: No known side lever knapsack sprayer of 15 litre capacity can be filled in 9 seconds. The Test Method was modified to 15 litres being poured from 2 buckets in 30 seconds each such that the overall rate was 15 litres/minute.

Spillage occurred as a consequence of inadequate flow through the filter basket, an insecure filter basket that orientated itself within the filling hole to the vertical position or, surprisingly, due to inadequate tank capacity. In two cases - although the sprayers are rated for a 15 litre capacity - there was no additional tank volume for liquid surge and/or splash at the end of the filling cycle.

Three sprayers [HSE 1, 4 and 6] passed the proposed limit of <100 mls [Table 4] and this value is likely to be a reasonable threshold value to set. We noted that at the start of liquid flow from the bucket, a small volume of test liquid, frequently failed to reach the filling orifice.

Table 4
Splash volumes; mls of spray solution

HSE 1	14
HSE 2	827
HSE 3	890
HSE 4	41
HSE 5	421
HSE 6	81
HSE 7	264

Note: The Test Method should be modified to the lower flow rate of 15 litres in 60 seconds. Test liquid should be poured from a specified height and derived values should consider the small, variable "start up" spilled volume.

LEAKAGE: IS TEST 5.4

Fill the sprayer with water and the tracer dye to the nominal capacity. Operate the sprayer such that all functions have been in use. Place the sprayer on a bench for a specified time and allow its lance assembly with hose and closed trigger valve to freely hang. Leave the sprayer for the appropriate time and examine for leakage.
The test shall be conducted with the sprayer in a vertical as well as in a horizontal [strap side down] position.

Comments: A poor design of connection to the base of the tank of HSE 7 leaked enough for it to just fail the "vertical" requirement of < 5 mls/5 minutes [Table 5]. Strap side down, this connection was now the highest point and there was less leakage. Poor assembly of the gland that seals the top of the piston to the tank on HSE 6, prompted a massive loss that easily failed the suggested <100 mls/5 minutes when sprayers are strap side down. A repeat test after the gland was correctly positioned and tightened would permit a pass. Thus, with just one slight improvement, all machines would pass the suggested limits. This general, encouraging trend could permit a reduced threshold limit for leakage from the strap side down position of <50 mls - a limit that would still permit 4 of the 7 machines to pass.

Table 5
Leakage; mls/5 minutes of spray solution

	Vertical	Strap side down
HSE 1	3	83
HSE 2	0	1
HSE 3	2	20
HSE 4	2	2
HSE 5	1	43
HSE 6	0	843
	After gland tightening	73
HSE 7	6	3

Note: The Standard should permit the Tester to make checks to the machine which would follow normal user practice. This study protocol assumed that machines were ready for use on removal from their box but, to avoid re-testing, it is sensible to allow final adjustments; providing they are within the limits of normal operator use.
It is suggested: ……*...nominal capacity. Hand check for normal tightness the filling cap, gland nut and other operator controlled couplings. Operate….*
The strap side down Performance Limit could be made more demanding and, it is again proposed, to unify both limits to < 5 mls/5 minutes.

STABILITY: IS TEST 5.2.6

The sprayer is to be placed in all orientations with its base on an incline of 10%. The test is to be performed with an empty and full tank.

Comments: All sprayers passed [Table 6]. However, although this is not a demanding slope, some sprayers [HSE 2 and 4] when faced down the gradient were only just able to stay upright. Indeed, the lever of HSE 2 was critical to its stability. It was felt that if an operator tried to fill the machine that these few sprayers could topple over. It is suggested that a steeper gradient be used.

Table 6
Stability

Sprayer:	Empty				Full			
Side facing down slope:	Front	Left	Rear	Right	Front	Left	Rear	Right
HSE 1	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
HSE 2	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
HSE 3	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
HSE 4	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
HSE 5	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
HSE 6	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
HSE 7	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Note: If the basis for this test is to ensure stability on a slope when the operator is carrying out normal functions then the Test Method may need to be made more demanding. It is suggested to use an incline of 15%.

STRAPS: IS TEST 5.2.3

The test shall be performed with the test bench equipped with a bar of 75 mm diameter to allow the sprayer to drop in a vertical position onto the straps. The drop height shall be 300 mm. The sprayer tank is to be filled to its nominal capacity. Each and every load bearing strap is to be tested separately.

Comments: Only two sprayers passed this demand [HSE 3 and 7] when judged by obvious strap or fixing failure. In one case [HSE 2] the metal support frame was also damaged whilst in another [HSE 6], an insecure fastening clip to the frame, failed. The proposed limit is that no part of the straps or their fixing points shall be damaged; a difficult subjective assessment which, on further close examination, may show the two others would fail too. Manufacturers were asked to specifically comment on the drop height for this test and it is likely that they will ask for it to be lowered to 100 mm.

Table 7
Strap and fixture compliance

HSE 1	Fail
HSE 2	Fail
HSE 3	Pass
HSE 4	Fail
HSE 5	Fail
HSE 6	Fail
HSE 7	Pass

Note: The Test Method requires a drop from 300 mm with a full machine onto a solid bar - without any absorption from impact shock. It is likely that some damage is always likely to occur. In this study, we only observed the extreme cases where straps/fixing points broke - but all sprayers were likely to have some damage which would become more apparent if the tests were repeated. Suggest the drop height is reduced to 100 mm to more closely simulate that expected from normal practice.

IMPACT: IS TEST 5.3

The test shall be performed with the test bench that can reproduce a defined drop of the sprayer in a vertical position from a height of 600 mm on a wooden platform.
The sprayer is to be filled to its nominal capacity.
The test shall be repeated 6 times.

Comments: The base frame of HSE 2 had to be straightened before these tests since it was severely bent after failing the Strap Drop Test. We noted that five sprayers had no observable structural damage after all six Impact drops. One sprayer [HSE 4] had a broken skirt whilst another [HSE 6] had a broken pump handle parking clip. However, these are not the criteria for judgement for it is suggested that the sprayers shall now pass the leakage test.

It was quite clear [but not measured] that considerable liquid loss would occur with HSE 5 and 6 for their filling caps and gland nuts worked loose. Re-tightened and they may have been adequate. In addition, both HSE2 and 6 were so full of liquid that some was forced out of the tanks as it made impact during the test. In our judgement, three sprayers [HSE 1, 3 and 7] would not be more prone to leakage - without any adjustment after impact - yet remain free of any obvious damage.

However, the Test Method is flawed. For example, although HSE 4 was damaged, it may still have passed the subsequent leakage test. In contrast, HSE 7 may have not worsened its intrinsic leakage rate as a result of these Impact Tests yet it still failed the earlier Leakage requirement. It is suggested that, if possible, this test would benefit from a clearer definition of its ultimate requirements.

Table 8
Leakage after Impact Test; judged only

HSE 1	Pass
HSE 2	Fail
HSE 3	Pass
HSE 4	Fail
HSE 5	Fail
HSE 6	Fail
HSE 7	Pass

Note: In reasonable commercial practice, damage would be rectified and the operator should check for leakage. Suggest the Test Report notes damage, permits readjustment [such as filler cap, gland nut tightening] and/or repairs before the subsequent Leakage Test. However, WG 5 should also note that CEN Standards has to foresee the consequence of misuse and further guidance may be needed for this Test before it is finalised.

BURST TEST: IS TEST 5.5

Internal compression chambers of lever operated sprayers are to be subjected to a pressure of 2.5 times the maximum nominal spray pressure.

Comment: Relief valves that are fitted on some sprayers were activated such that the compression chamber is not over compressed. We have assumed that if this Fail-safe device is fitted and works then the machine would pass. The test pressure could not be attained in these cases.

In addition, both the internal compression chambers **and its supply hose to the trigger valve** were subjected to pressures of 2.5 times that which is the nominated maximum. It was considered more relevant to test all sprayer components that could be exposed to such pressures rather than laboriously remove the compression chamber and test in isolation. All sprayers passed.

Table 9:
Burst Test

HSE 1	Pass	Relief valve avoided over pressurising
HSE 2	Pass	Relief valve avoided over pressurising
HSE 3	Pass	Relief valve avoided over pressurising
HSE 4	Pass	
HSE 5	Pass	
HSE 6	Pass	
HSE 7	Pass	Relief valve avoided over pressurising

Note: The Test Method should distinguish between those sprayers with and without pressure relief valves. The text could be modified to -

Internal compression chambers of lever operated sprayers and their supply hose are to be subjected to a pressure of 2.5 times the maximum nominal spray pressure and/or relief valves where fitted are shown to be effective.

DURABILITY: IS TEST 5.2.1

The test shall be conducted using a special robot that operates the lever operated sprayer filled with 75% of its nominal capacity.
The test duration will be 250 hours, operating at a maximum of 30 cycles/minute with a spray pressure of 3 bars.
The sprayer shall remain functional.

Recent, alternative test data produced for commercial organisations by Thornhill on samples of HSE 5 and HSE 7 indicate that they would pass the durability test of 250 hours. Indeed, other sprayers have been tested for over 2000 hours and remain functional. However, it is not known whether these same machines would then pass all other tests - after this one for Durability - but the requirement proposed appears reasonable.

TEST SUMMARY

This research indicates that some of the test Methods will have to be modified whilst some will benefit from further clarification only. The Test Method that puts most doubt, on the value of the results, is that concerned with Internal Residues. We also believe the Strap Test is too demanding whilst that for Stability, Leakage and Durability may be too lenient. Others Tests also need better clarification and these have been indicated. Despite these limitations, it can be shown that from the 56 individual tests that were made some 22 passed - to suggest the overall Standard of 61% success is perhaps reasonable.

Table 10

The success or otherwise of the 7 UK purchased side lever knapsack sprayers at meeting the proposed IS Performance Limits when subjected to their Test Methods

Sprayer:	**HSE 1**	**HSE 2**	**HSE 3**	**HSE 4**	**HSE 5**	**HSE 6**	**HSE 7**
External deposits	Pass	Pass	Pass	Pass	Pass	Pass	Fail
Internal residues	Fail	Fail	Fail	Fail	Fail	Fail	Pass
Filling rate	Pass	Fail	Fail	Pass	Fail	Pass	Fail
Leakage	Pass	Pass	Pass	Pass	Pass	Fail	Fail
Stability	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Straps	Fail	Fail	Pass	Fail	Fail	Fail	Pass
Impact	Pass	Fail	Pass	Fail	Fail	Fail	Pass
Burst	Pass	Pass	Pass	Pass	Pass	Pass	Pass

COLLECTIVE PERFORMANCE

As a group, the sprayers coped too well with the Stability and Burst demands [Table 11]. It is also likely that External deposits and Leakage requirements could be made more demanding too. However, the Strap test is too harsh and that for Internal Residues is seriously flawed.

Table 11
Collective performance of all sprayers and all Test Methods/Performance Limits; % of all sprayers that passed

	External	**Internal**	**Filling**	**Leakage**	**Stability**	**Straps**	**Impact**	**Burst**
All sprayers:	85	14	43	71	100	29	43	100

There appear to be no outstanding type of side lever knapsack sprayer on the existing UK market and none are particularly poor [Table 12]. None passed all Tests and none failed them all either. The biggest surprises were with those whose capacities differed from that for which they were rated. Two - otherwise very good sprayers - went on to fail Tests for both Filling rate and Impact [Test liquid was forced out].

It is encouraging to note that where manufacturers have needed to make improvements [Leakage and External deposits], these benefits are now on sprayers and in the UK market place.

Table 12
Collective performance of individual sprayers with all tests; %

	HSE 1	HSE 2	HSE 3	HSE 4	HSE 5	HSE 6	HSE 7
All tests:	75	50	75	63	50	50	63

CONCLUSIONS

The HSE can justifiably ask British Standard AGE 15 committee [Chairman: Prof Paul Miller of SRI] to consider improvements to some of the proposed IS Test Methods. In addition, they may wish to suggest that some of the Performance Limits can be made more demanding whilst others may benefit from being less so.

HSE will be reassured to note that manufacturers have responded to their earlier wish for better design, and the improvements introduced, can now be monitored.

The relationship between these Tests and their Performance Limits, with subsequent operator exposure, should be established; further improvements from manufacturers are likely but, in doing so, they may put their product at a financial disadvantage unless this final link that underpins all this progress, is well and truly established.

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