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Independent Evaluation Report

regarding the

Usability of the "KeyKeg" One-Way Keg for Beer

Test Phase II

prepared on behalf of

Lightweight Containers BV

Takelaarsweg 10

1780 Den Helder, The Netherlands

This report contains 20 pages, including this cover sheet.

Freising-Weihenstephan, 8 July 2008

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1 Task

Lightweight Containers BV, headquartered in Den Helder, The Netherlands, has developed a one-way keg for beverages. The keg sizes currently on offer on a regular basis are 20 and 30 litres.

The Chair for Process Engineering at the Weihenstephan Science Centre, Technical University of Munich, has been commissioned with evaluating these kegs as to their general usability for beer in comparison to stainless steel kegs.

Following the completion of a first testing phase in December 2007, several keg design improvements have been implemented. The design of the new series of kegs to be evaluated used the findings established during the first series of tests. The effectiveness of these improvements has been evaluated in a second series of tests carried out from December 2007 to June 2008. The first-series test report has already been submitted to Lightweight Containers BV, Den Helder, The Netherlands.

The re-designed kegs have been evaluated on the basis of the following criteria:

- Sensory evaluation (tasting exercises),
- Oxygen,
- CO_2,
- Storage: at 28°C, for 6 months, testing after 4 and 6 months,
- Extreme conditions test: Storage temperatures alternately changing from 45°C for 8 hours to 28°C for 16 hours over a 3-week period,
- Options for technical optimisation.

The beer to be evaluated was refilled into stainless steel kegs and KeyKegs in order to enable a direct quality comparison. Also, “Helles” and “Weißbier” brewed at the Weihenstephan State Brewery were again used as testing media.

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2 Description of the KeyKeg

2.1 Composition of Containers

The one-way containers evaluated were 20- and 30-litre kegs as shown in Fig. 1 to 3.

Fig. 2. Empty KeyKeg.[1]

Fig. 3. Filled KeyKeg.[2]

Fig. 4. KeyKeg with outer packaging[3]

The composition is shown in Fig. 4.

[1] Source: http://www.keykegbeer.keykeg.com
[2] Source: ibid.
[3] Source: ibid.

Fig. 4: Composition of the KeyKeg[4]

The keg is contained in an outer carton packaging enclosed by a plastic film. This packaging provides dirt protection to the container.

On its inside, the keg includes a PET ball in which an inner liner is located. This inner liner is fitted with a layer of aluminium to minimise oxygen and carbon dioxide diffusion.

Fig. 5: Inner liner with de-aeration aid (serrated film, white)

[4] Source: http://www.keykegbeer.keykeg.com

In Fig. 6, a folded inner liner with de-aeration aid is shown, as used in the most recently tested containers.

The KeyKeg is connected via a special dispensing head supplied by Dispense Systems International (DSI) or Micromatic.

Since beer is dispensed by compressing the inner liner, the intermediate space is filled with pressurised air.

The kegs used for the tests at the Department were prototypes ready for series production that consisted of the components to be used but had been assembled manually.

2.2 Requirements on the Containers

The containers are mainly designed to replace stainless steel kegs in their expensive export to foreign countries. For this reason, the kegs must also withstand, without any compromise to quality, extreme conditions in containers, at sea and at harbours.

The newly developed kegs should fulfil the requirement to supply a beer quality very similar to beer filled into stainless steel kegs.

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3 Experimental Setup

As briefly described under Item 1, the kegs were evaluated according to various testing parameters. In parallel, stainless steel kegs were tested in order to arrive at a direct comparison of the two keg types. Also, two types of beer were tested ("Weihenstephaner Original", "Weihenstephaner Hefeweißbier").

The stainless steel kegs were filled via the standard keg filling unit at the Weihenstephan State Brewery. The KeyKegs were filled manually directly from the pressurised tank. In this process, the fitting area was disinfected with an alcoholic solution, and fitted with sterile caps.

The kegs were then stored in a climate chamber at the Department for Process Engineering.

After pre-defined intervals (4 and 6 months), 3 kegs in each keg category and beer type were evaluated with regard to the above testing parameters. In the course of a second filling, which included further technical improvements, these kegs were also simultaneously stored in the climate chamber at 28°C. These kegs were sampled after expiry of a 4-month period.

Some of the kegs were again exposed to extreme conditions, yet without loading (as this test had already been passed), at 28°C and 45°C, and subsequently sampled.

3.1 Storage of Kegs for Long-Term Test

The temperature was set to 28°C in order to simulate overseas transport. The test temperature was selected on the basis of findings established by data logging devices used in preliminary tests.

The testing period comprised 6 months.

3.2 Storage of Kegs for Extreme-Conditions Test

For the extreme-conditions test, the temperature was set slightly above the historical values recorded by data logging devices. This test was designed to evaluate the extent to which the kegs would tolerate very high temperatures. During the test, the temperature was alternately set to 45°C for 8 hours and to 28°C for 16 hours. The humidity was set to 50%.

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The extreme-conditions test was carried out over a period of 21 days. Interim samples were taken after 14 days. According to information obtained from several sources, the average keg storage time equals 14 days.

4 Conduct of Analyses

4.1 Microbiological Tests (Test Phase I)

For the microbiological tests, samples were taken from both the stainless steel kegs and the KeyKegs using a sterile dispensing head, membrane-filtered and subsequently incubated on NBB-A under aerobic and anaerobic conditions for 5 days at 28°C.

4.2 Colour Measurements (Test Phase I)

Colours were measured photometrically using the EBC method.

4.3 Tastings

The MEBAK triangle test was used for sensory evaluation.

4.4 Oxygen Measurements

Oxygen measurements were carried out using an Orbisphere Gas Analyzer.

4.5 CO_2 Measurements

For the CO_2 measurements, a Hafmanns CO_2 meter was provided.

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5 Test Results – Summary and Overview of Test Phases I and II

5.1 First-Series Testing Criteria Met

5.1.1 Microbiological Tests

During the first series of tests, microbiological samples were analysed for all kegs. No contamination was found in these samples. No abnormalities were detected in any of the samples.

5.1.2 Colour Measurements

In addition, the first series of tests included measurements of a possible change in the beer colour. These measurements led to the following results.

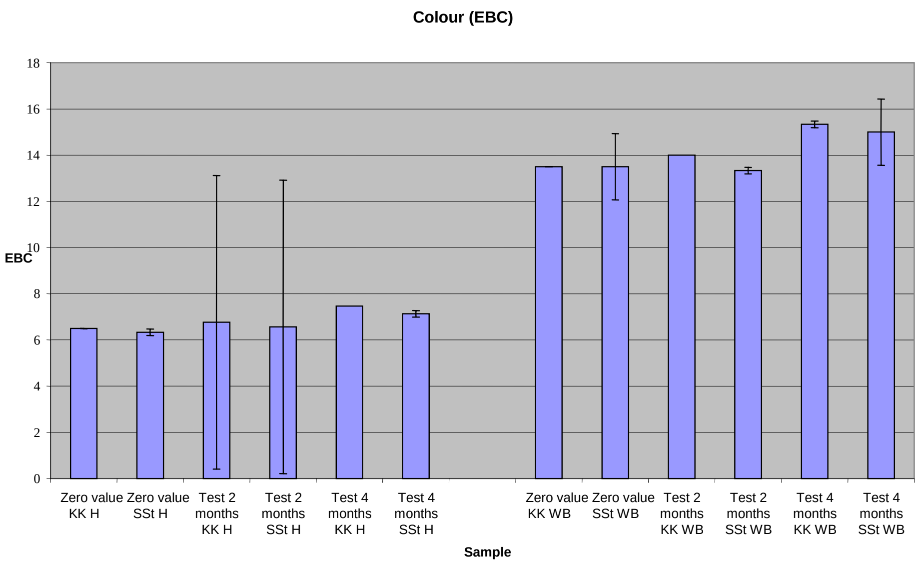

Fig. 6. Changes in beer colour over testing period

As shown in Fig. 6, a slight increase in colour intensity is noticeable both for beers in the stainless steel kegs and in the KeyKegs. For the "Weißbier" samples, an increase in the mean values could be detected but was not significant due to the high confidence intervals.

For the "Helles" samples, a minor, significant increase in colour intensity could be detected for both keg types.

5.1.3 Loading Test to Simulate Stacking in Containers

The loading tests were to establish whether the design of the kegs provided sufficient stability also at high temperatures. For this purpose, the kegs were

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exposed to extreme conditions. These conditions served to simulate a container storage during which the bottom layer of kegs was evaluated as the "worst case" in relation to keg stability.

For this purpose, the temperature was aligned to the historical values recorded by data logging devices. The temperature was alternately set to 42°C for 8 hours and to 28°C for 16 hours. The humidity was set to 50%. The 20-litre kegs were loaded with 620 kilograms, which corresponds to the load acting on the bottom layer of a pallet. The test was carried out over a period of 14 days, which is equivalent to a realistic container storage period at a harbour.

Purely on the basis of visual inspections from outside, the kegs passed the test without damage. Following the loading test, the CO_2 content was 3.5% lower than the value measured immediately before.

Fig. 7: One layer of KeyKegs loaded with 620 kg

5.2 Results of the Analyses in Test Phase II

5.2.1 Oxygen Measurements

During the testing period, no oxygen uptake could be measured in the containers.

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5.2.2 CO_2 Measurements

For reasons of clarity, the results of the CO_2 measurements are shown separately in the following diagrams. A comparison is made between the keg types, depending on the type of beer, storage conditions and filling dates.

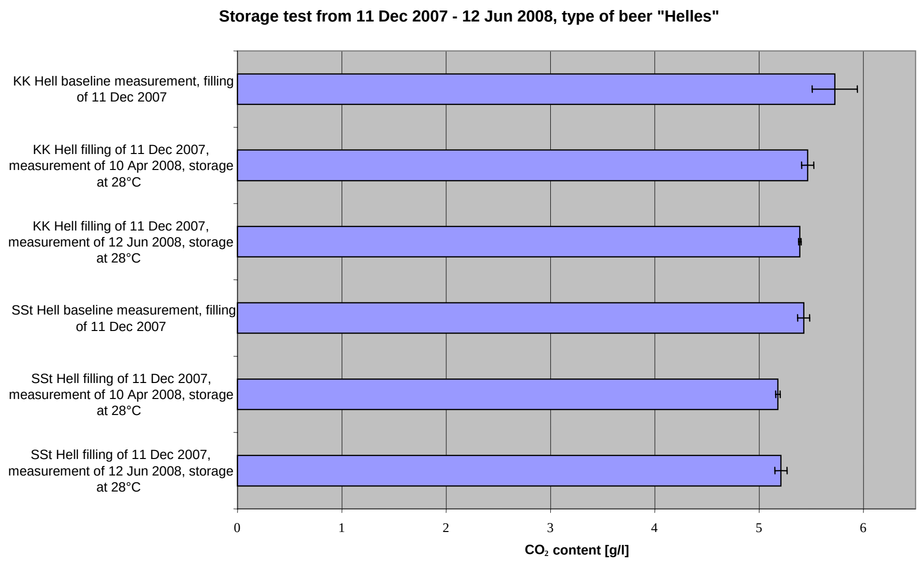

Fig. 8: Trend of measured CO_2 values for "long-term test", "Helles" beer type, filling of 11 December 2007

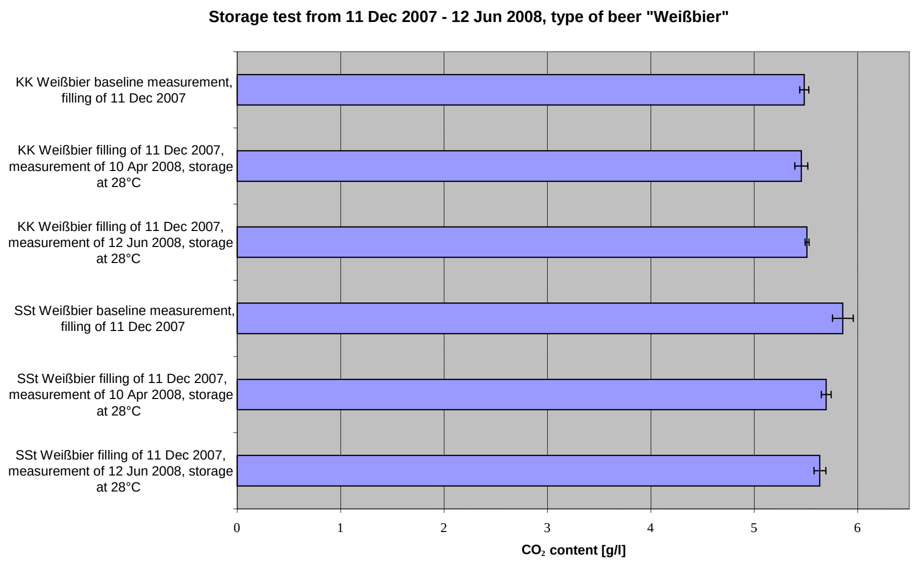

Fig. 9: Trend of measured CO_2 values for "long-term test", "Weißbier" beer type, filling of 11 December 2007

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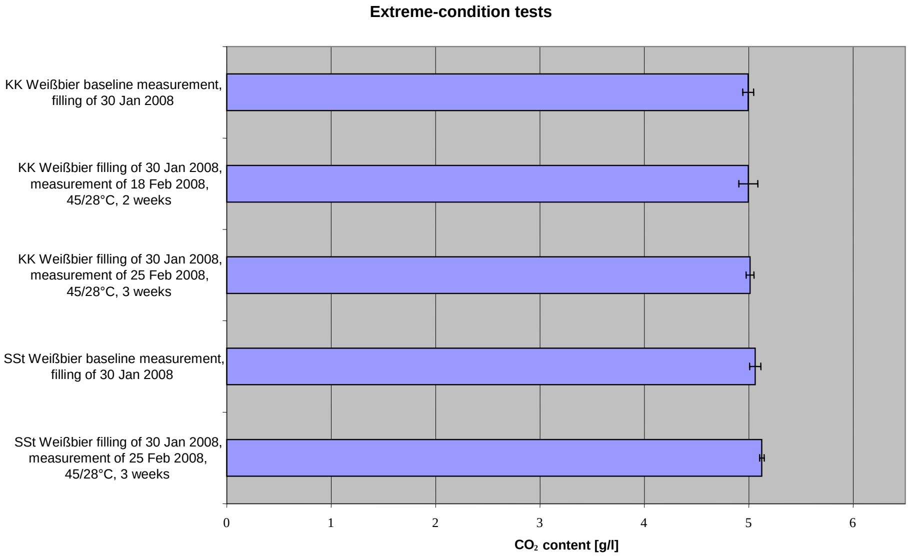

Fig. 10: Trend of measured CO_2 values for "extreme-conditions test", "Weißbier" beer type, filling of 11 December 2007

As shown in Fig. 8 to Fig. 10, no or only a minor reduction in the CO_2 content could be detected. This indicates that the current, revised keg designs are appropriate to retain the beer quality in terms of its CO_2 content.

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5.2.3 Tasting Results

The long-term tests were always accompanied by tasting exercises carried out at the applicable intervals (triangle tests according to MEBAK, comparing stainless steel keg to KeyKeg). The results are outlined in the following log extracts. In none of the tasting exercises carried out could a significant difference between the two keg types be detected.

The group of tasters were recruited from employees at the Process Engineering Department.

5.2.3.1 Triangle Test of "Weißbier" in Stainless Steel Keg and KeyKeg on 25 February 2008

- Venue: O 18, MAK Weihenstephan
- Testing medium: "Weißbier", filled on 11 December 2007
- Participants: 18
- Correct result: 7
- Incorrect result: 11
- For a significance with a 95% confidence, 10 correct answers would have been required.

5.2.3.2 Triangle Test of "Weißbier" in Stainless Steel Keg and KeyKeg on 10 April 2008

- Venue: O 18, MAK Weihenstephan
- Testing medium: "Weißbier", filled on 11 December 2007
- Participants: 15
- Correct result: 3
- Incorrect result: 12
- For a significance with a 95% confidence, 9 correct answers would have been required.

5.2.3.3 Triangle Test of "Weißbier" in Stainless Steel Keg and KeyKeg on 12 June 2008

- Venue: O 18, MAK Weihenstephan
- Participants: 19
- Correct result: 8
- Incorrect result: 11

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- For a significance with a 95% confidence, 11 correct answers would have been required.

5.2.3.4 Triangle Test of “Helles” in Stainless Steel Keg and KeyKeg on 12 June 2008

- Venue: O 18, MAK Weihenstephan
- Participants: 14
- Correct result: 5
- Incorrect result: 9
- For a significance with a 95% confidence, 9 correct answers would have been required.

5.2.4 Other Observations

5.2.4.1 Stability of Inner Liner

The first series of tests revealed weaknesses in the inner liner design. Lightweight Containers BV was able to resolve these problems very effectively. During the new filling process, only one keg of the December filling was identified where the inner liner was damaged at the fitting. Compared to the number of kegs filled and to the performance of the previously used inner liners, this does not constitute a noticeable deficiency. In addition, this failure has been overcome by using a new material.

5.2.4.2 Loss of Stability During Moisture Impact

Following the keg measurements, the kegs showed traces of splashing beer. These were removed by applying a water jet. As a result, the protective outer carton around the kegs became soaked. In relation to the outer carton packaging, it could be observed that the stability and handling ability got lost as a result.

5.2.4.3 Stability of PET Ball During Impact of Sharp Objects

For logistics reasons, the kegs need to be dismantled and cut into pieces prior to being recycled. This poses a burst risk if the applied pressure is not evacuated before. As a solution to this problem, Lightweight Containers BV offers a de-aeration adapter to be used for keg pressure relief. Following this procedure, the kegs can be cut into pieces safely and easily.

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In addition, the response of the kegs to the impact of sharp objects was evaluated. Two tests were carried out for this purpose. During the first test, a completely filled keg was cut with a wallpaper trimmer. The keg burst as a result, and a splash of beer poured out of the keg. In the second test, the PET ball was manipulated with a sharp object after removal of the protective envelope. This also led to the bursting of the keg.

In general, it was found that the PET ball did not distribute sharp fragments. The broken edges can be considered almost safe, no sharp-edged zones were found. The ball bursts into two halves but remains a coherent unit in material terms. In terms of damage, the resulting shock and the risk of the beer spreading across the room should be mentioned. Although physical injury cannot be excluded entirely, the testers consider the associated risk low to almost non-existent.

In response to this outcome, a notice was added to the protective envelopes of the kegs, warning against the use of sharp objects while handling the keg.

5.2.4.4 Dispensing Pressure

It was found that the valve did not always close completely after disconnection of the keg. This became apparent by the beer foaming in the fitting and by the fact that the beer tasted stale due to the CO_2 loss after several days of storage.

This is usually irrelevant since the kegs are designed to be connected and dispensed until they are empty. If, however, the keg is disconnected, put to interim storage and reconnected, a working pressure of at least 2.5 bar (gauge) should be applied since, otherwise, the valve will not close properly again.

5.2.4.5 Mould Formation

Strong beer splashing occurred during the dispensing process, in particular in the case of half-empty kegs. The beer flowed off the fitting into the space between PET ball and carton packaging. In kegs that were retained as samples at the Department for a subsequent period, mould formation could be observed at a later point in time, which was due to the spilled beer.

Similar observations were made in the fitting. This is where beer is collecting after dispensing. If beer residues are not removed by using, for example, a cloth, moulds will form also in this area.

However, these findings do not pose any further problems either during normal use (which means to fully dispense the keg content in a single pass).

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Following the completion of all tests, it can be concluded that the kegs evaluated are an appropriate alternative to conventional stainless steel kegs.

6 Outlook

The Chair for Process Engineering kept Lightweight Containers BV continuously informed of the observations made in the course of the tests. On the occasion of several visits, the interim results (such as defective kegs in the first testing phase) were jointly inspected. In this process, weaknesses were detected and discussed.

Lightweight Containers BV has revised the critical points and re-designed vulnerable parts. These modifications were presented to the experts and thoroughly tested in a new series that started in December 2007.

7 Summary

On behalf of Lightweight Containers BV, the Chair for Process Engineering has tested the new “KeyKeg” one-way keg under extreme conditions in two independent test phases. These tests served to evaluate the usability of the new kegs for beer in comparison to conventional stainless steel kegs, and to simulate their suitability for transport on overseas routes.

It was found that the new kegs are an innovative solution for the export beer market.

In terms of microbiological stability, transport stability, beer colour and oxygen uptake, the new kegs proved well-suited to the use for beer. In addition, no noticeable CO_2 loss was detected compared to conventional stainless steel kegs. The opportunities for improvement identified in Test Phase I were successfully implemented by Lightweight Containers BV. The re-design of the fitting area and a completely new inner liner design contributed to a significant quality improvement.

None of the tasting exercises revealed a significant result.

Following the completion of all tests, it can be concluded that the kegs evaluated are an appropriate alternative to conventional stainless steel kegs.

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