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EXAMINATION OF SHIPPING PACKAGES 9975-01818, 9975-01903 AND 9975-02287

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Summary

Three 9975 shipping packages were examined to investigate the non-conforming condition of an axial air gap greater than 1 inch. This condition typically indicates the presence of excess moisture in the fiberboard overpack, and may be accompanied by degradation in the fiberboard properties. The package with the largest axial air gap (9975-01818, with an air gap of 1.437 inches) was found to contain significant excess moisture, and the lower fiberboard assembly was covered with mold and was significantly degraded in strength. This condition is very similar to that observed previously in package 9975-01819. Both packages (-1818 and -1819) appear to contain a similar amount of excess moisture, which was previously estimated for 9975-01819 as ~2.5 liters. The condition of 9975-01818 was also evidenced by several rust spots along the bottom chime of the drum, although no significant rust was noted on the closure bolts.

Packages 9975-01903 and 9975-02287 were also examined. The axial air gap in these two packages was less than in 9975-01818, but still exceeded 1 inch. These two packages contained elevated moisture levels, although not significantly higher than seen in other "typical" packages. The fiberboard in these two packages was of sound integrity, and appeared generally consistent with undegraded material. A few small patches of mold on and near the bottom of the fiberboard in 9975-01903 appeared dormant. No mold was observed on package 9975-02287.

The SPA will provide recommendations on possible follow-up activities with these three packages. This might include a demonstration in SRNL of whether removal of the caplugs from similar packages would facilitate removal of excess moisture. Future efforts should also include an assessment of using the 1 inch axial gap criterion as a valid indicator of fiberboard degradation.

Background

On September 23, 2009, three 9975 shipping packages (-01729, -01836 and -01879) were examined in KAMS following identification of a non-conforming condition [1]. The axial air gap at the top of each package exceeded the acceptance criterion of 1 inch. Follow-up discussions of these packages involved the identification of several additional packages with the same non-conforming condition, and recommendations from the Surveillance Program Authority (SPA) aimed at better understanding of the significance of this condition, and to establish an appropriate path forward to explain and disposition the observations [2].

In accordance with one of the SPA recommendations, three additional 9975 packages (-01818, -01903 and -02287) with the same non-conforming condition were identified for examination. This examination was performed on October 26, 2009 by SRNL-MS&T (Daugherty), SRNL-SRPT (Murphy, Watkins) and NMM Engineering (Hackney) [3]. This report documents the results of that examination.

Examination Results

Packages 9975-01903 and 9975-02287 had a normal appearance from the outside, with no apparent degradation. Package 9975-01818 had several rust spots along the bottom chime of the drum, particularly at the ends of the tack welds (see Figure 1).

Several measurements and observations were made on each of the 3 packages to characterize the moisture content of the fiberboard overpack and its overall integrity. Before opening each package, one caplug was removed and a probe was placed in the top airspace through the caplug hole to record the relative humidity. The results are shown in Table 1.

In addition, when 9975-01818 was opened, the humidity probe was inserted down the side between the drum and fiberboard approximately 12 inches, and the lid replaced while the probe came to equilibrium. At this location (~4 inches below the top of the lower fiberboard assembly), the probe indicated 75.5% RH and 21.7 C.

For each package, the upper fiberboard assembly was removed for weight, moisture content and dimensional measurements. During these measurements, the lid was placed on the drum to minimize moisture loss from the lower fiberboard assembly. Then the containment vessels, shield and lower fiberboard assembly were removed. The lower assembly was characterized in the same manner as the upper assembly. Each package was then re-assembled and closed. In the case of 9975-01903, the lead shield was stuck in the lower fiberboard assembly and could not be lifted out. The shield and lower assembly were removed together, and the accessible dimensions were measured.

Average weight and dimensional data for each package are summarized in Table 2. In most cases, the measured values are consistent with nominal drawing dimensions. The primary exception is the height of the lower assembly (dimension LH1) for packages 9975-01818 (0.61" short) and 9975-01903 (0.29" short).

The moisture content data for each package are presented in Figures 2-4. Package 9975-01818 had the highest moisture content, and also had extensive mold growth. The exterior of the lower assembly was completely covered with mold (Figure 5), and regions of the upper assembly contained mold (Figure 6). Significantly lower moisture content was measured on the other two packages, although the higher values measured on these packages are slightly greater than seen on other "typical" packages. Package 9975-01903 contained several small patches of mold near the bottom of the lower assembly (Figure 7), while no mold was observed on 9975-02287. The mold on 9975-01903 appeared dormant, with an absence of the fine filament structure typical of active mold.

Varying degrees of corrosion were seen on the lead shield of each package, and the variation was not necessarily in proportion to the moisture content of the fiberboard. Each shield is shown in Figure 8 for comparison. The shield from 9975-02287 had a heavy band of corrosion around the bottom several inches, and light corrosion elsewhere. The shield from 9975-01818 had a more uniform moderate corrosion over its entire surface. The portion of the 9975-01903 shield which protruded from the lower fiberboard assembly was relatively heavily corroded.

A qualitative test was performed on the 9975 -01818 fiberboard to illustrate the extent to which the compressive strength has been compromised in the lower assembly. This test measures the depth of penetration into the fiberboard of several allen wrenches. Since the fiberboard in this package was considered too degraded (from mold, loss of strength and dimensional changes) to return to service, performance of this test would not impact facility operations. This test was not performed on the other two packages since they did not appear to be significantly degraded, and could be cleared to return to service.

At several locations along the OD and bottom surfaces, each of 3 allen wrenches was pressed into the fiberboard with approximately the same force. Each impression on the side was located between glue joints. The wrenches were 4, 6 and 8 mm in size. See Figure 9. The depth of impression was recorded at each location, along with the moisture content. The same steps were performed on a separate section of relatively dry fiberboard (7.8 % wood moisture equivalent, WME), for comparison. Results are summarized in Table 3. While these results cannot be converted directly into a measure of the fiberboard compressive strength, they do illustrate that significant loss of strength has occurred.

The bottom of the drum is dished, such that the bottom of the lower fiberboard assembly contacts the drum around the outer edge. Some portion of the fiberboard is compressed to increase the contact area and reduce the contact stress. Typically, this compressed region is roughly 2 inches wide, consistent with the observations of 9975-01903 and 9975-02287 (Figures 7 and 10). In contrast, the entire bottom of 9975-01818 lower fiberboard assembly had conformed to the bottom of the drum (Figure 11), as seen by the impression of lettering from the drum. The convexity of the drum bottom is required to be at least 0.37 inch [4].

Discussion

Several changes in the fiberboard properties are expected as a result of increased moisture. Initial changes include an increase in density, an increase in the thermal conductivity and heat capacity, and a decrease in compressive strength. Over time, additional changes are possible due to the continued presence of excess moisture. In addition, biological processes (e.g. mold or bacteria) can develop over time and introduce additional degradation routes. The rates of biological and physical degradation mechanisms would vary with the local environment within each package, but little data currently exist to help estimate these rates. These changes should be evaluated for any impact on package performance in KAMS. A more detailed analysis would be needed to quantify the full impact.

When excess moisture is present, the highest moisture levels will tend to occur at the bottom of the package. This is due to the influence of gravity as well as the thermal gradient that will develop with an internal heat load which will tend to drive moisture to cooler regions of the package. With all three of the packages examined, the higher moisture content was observed at the bottom of the lower fiberboard assembly. This region is also the most likely source of fiberboard height reduction (causing the axial gap to exceed 1 inch), since it combines the highest moisture content with the greatest stress (under the lower bearing plate). The dimensional data support this contention for 2 of the packages, based on the following.

- The nominal air gap between the air shield and drum flange is 0.8 inch [4].
- The overall upper fiberboard assembly height is the sum of dimensions UH1 and UH2 (refer to the sketch in Table 2). In all 3 packages, this sum falls within drawing tolerances of the nominal value (9.2 inches [6]), allowing for the thickness of the air shield.

- The thickness of the lower bearing plate and the fiberboard below it is given by dimension LH1 minus dimensions LH2 and LH3, with a nominal value of 4.3 inches [6]. For 9975-01818, this difference is 3.67 inches, with a nominal reduction of 0.63 inch. This reduction corresponds to the axial air gap of 1.437 inches, which is 0.637 inch greater than nominal.
- The thickness of the lower bearing plate and fiberboard below it could not be calculated for 9975-01903 since dimension LH2 could not be measured. However, dimension LH1 is 0.29 inch less than the nominal value. The axial air gap for this package is 0.35 inch greater than nominal. Therefore, the dimensional change in this package definitely occurred within the lower assembly.
- For 9975-02287, the difference between dimension LH1 and LH2+LH3 is 4.25 inches (within tolerances of nominal dimensions). The axial air gap for this package was 1.008 inch, or 0.208 inch greater than nominal. With a tolerance on each dimension of +/- 0.05 inch, and no record of as-built dimensions, it is not possible to identify the source of the increased axial air gap for this package.

Package 9975-01819 was previously examined [5] following the observation of an axial air gap greater than 1 inch, and the presence of mold on the upper fiberboard assembly. Measurements made on that package and subsequent calculations indicated that approximately 2.5 liters of excess water were present in the fiberboard. Comparing the moisture readings from that package with those for 9975-01818 suggests a strong similarity. The bottom layers of 9975-01818 probably contain somewhat less moisture (e.g. the reading at bottom center of 60%WME vs 100%WME for 9975-01819), but the rest of the fiberboard had somewhat higher readings. Accordingly, it is likely that 9975-01818 contains about the same amount of excess moisture (approximately 2.5 liters).

The discussion in Reference 5 regarding degradation of fiberboard properties in 9975-01819 due to excess moisture are equally applicable to the current condition of 9975-01818, which has a similar amount of excess moisture and a heavier accumulation of mold. In contrast, the fiberboard in 9975-01903 and 9975-02287 remains sound and consistent in appearance with new material, except for the small patches of mold on 9975-01903 (Figure 7). However, these patches of mold on 9975-01903 did not appear to be actively growing since they lacked the fine filament structure typical of active mold.

An additional influence on package integrity that has not been evaluated is the effect of mold. In the earlier stages of mold growth, the presence of additional material (the mold structure itself) will tend to fill some of the available pores in the fiberboard, which may lead to modest increases in the compressive strength and thermal conductivity. At some point after significant growth occurs, the mold will begin to degrade the fiberboard fibers, and replace the cellulose structure with decomposition by-products. The impact of this on strength and thermal properties is unknown, but it is suspected that the strength will decrease significantly (beyond the changes attributed to excess moisture). Also unknown is the timeframe for such changes to occur.

Conclusions and Path Forward

Three 9975 shipping packages were examined to investigate the non-conforming condition of an axial air gap greater than 1 inch. This condition typically indicates the presence of excess moisture in the fiberboard overpack, and may be accompanied by degradation in the fiberboard properties. In the case of package 9975-01818, which had the largest axial air gap, the fiberboard was found to contain significant excess moisture, and the lower fiberboard assembly was covered with mold and was significantly degraded in strength. This led to compression of the bottom layers of fiberboard, which increased the axial air gap to its present value. Further suggestion of the excess moisture was indicated by the presence of several rust spots along the bottom chime of the drum. There was no observation of significant rust on the closure bolts.

The other two packages contained elevated moisture levels, although these levels are near the high end of the range seen in other "normal" packages. The fiberboard in these two packages was of sound integrity, and appeared consistent with undegraded material.

The SPA will develop recommendations on future SRNL activities based on one or more of these and other packages with excess fiberboard moisture. It is desirable to demonstrate an effective means to identify and remove excess moisture, such as by removal of the caplugs.

The investigation of these three packages was triggered by discovery of an axial gap exceeding 1 inch. This limit is based on the 9975 SARP, and represents a deviation of 0.2 inch in the fiberboard assembly height versus the nominal as-fabricated height. It is desirable to confirm whether this criterion is an appropriate value for screening packages that might contain excess moisture, mold or other undesirable internal conditions. Future activities should include an assessment of this criterion as a valid indicator of fiberboard degradation.

References

1. "9975 Fiberboard Inspection Notes - DRAFT", email from J. Murphy dated 9/23/2009

2. SRNL-L7200-2009-00017, "Surveillance Program Authorization Recommendations for 9975 Axial Gap Issue", K. A. Dunn, E. R. Hackney, J. W. McClard and D. B. Rose, October 8, 2009

3. "9975 Examinations for Axial Gap NCRs - Summary", email from J. Murphy dated 10/26/2009

4. Drawing R-R2-F-0025, Rev. 2, "9975 Drum with Flange Closure Subassembly and Details", October 29, 2003.

5. SRNL-STI-2009-00240, "Examination of Fiberboard from Shipping Package 9975-01819", W. L. Daugherty, April 2009

6. Drawing R-R2-F-0019, Rev. 5, "9975 Shipping Package Insulation Assembly, Subassemblies and Details", July 30, 2002

Table 1. Humidity data for package airspace

Package	9975-01818	9975-01903	9975-02287
Airspace Relative Humidity	67.5%	51.8%	56.9%
Airspace Temperature	22.4 C	22.5 C	22.9 C
Room ambient conditions	44.0%, 21.3 C	42.4%, 21.1 C	46.2%, 20.5 C
Time of measurements	~1000 hrs	~1300 hrs	~0900 hrs

Table 2. Physical measurements (averaged values) of fiberboard assemblies.

	9975-01818	9975-01903	9975-02287	R-R2-F-0019 Rev 5 Nominal value (inch)
Axial air gap (in)	1.437	1.152	1.008	
Upper assembly				
UD1 (in)	17.655	17.654	17.636	17.7
UD2 (in)	8.572	8.584	8.544	8.55
UR1 (in)	3.035	3.016	3.062	3.075
UR2 (in)	1.483	1.521	1.490	1.5
UH1 (in) *	7.205	7.144	7.086	7.1
UH2 (in)	2.056	2.122	2.165	2.1
UH3 (in)	4.990	5.01	5.038	5.0
Weight	27.2 lb	27.5 lb	26.5 lb	
Calculated density	0.277 g/cc	0.283 g/cc	0.269 g/cc	
Lower assembly				
LD1 (in)	18.090	18.088	18.093	18.1
LD2 (in)	8.446	8.376 (shield)	8.468	8.45
LR1 (in)	3.271	Not measured	3.238	3.275
LR2 (in)	1.528	Not measured	1.540	1.55
LH1 (in)	26.09	26.41	26.66	26.7
LH2 (in)	20.385	Not measured	20.355	20.4
LH3 (in)	2.038	2.059	2.059	2.0
Weight	59.3 lb	Not measured	58.2 lb	
Calculated density	0.293 g/cc	NA	0.279 g/cc	

* Measured values of dimension UH1 include the air shield. The average is reduced by 0.1 inch in calculating assembly density.

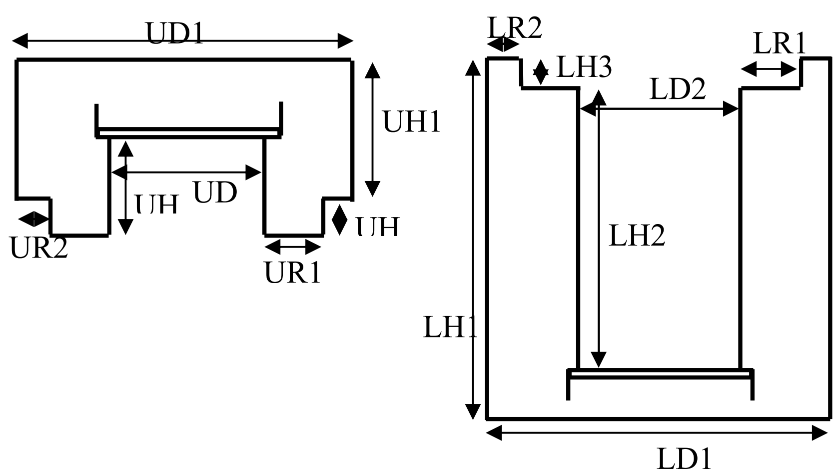


Table 3. Relative strength of 9975-01818 lower fiberboard assembly as indicated by penetration of allen wrenches

Location	%WME	Penetration by 4 mm wrench	Penetration by 6 mm wrench	Penetration by 8 mm wrench
9975-01818				
OD, ~11.2 inches from bottom	25.0	13/16 inch	5/8 inch	1/4 inch
OD, ~6.8 inches from bottom	24.4	7/16 inch	5/16 inch	3/16 inch
OD, ~2.2 inches from bottom	50	1 5/16 inches	1 3/16 inch	7/16 inch
Bottom, ~1.5 inches from side	100	5/8 inch	1/2 inch	3/8 inch
Control section				
Control section, side	7.8	< 1/16 inch	< 1/32 inch	< 1/32 inch

Figure 1. Rust spots along the bottom chime of 9975-01818 drum. Photograph provided by NMM (Hackney).

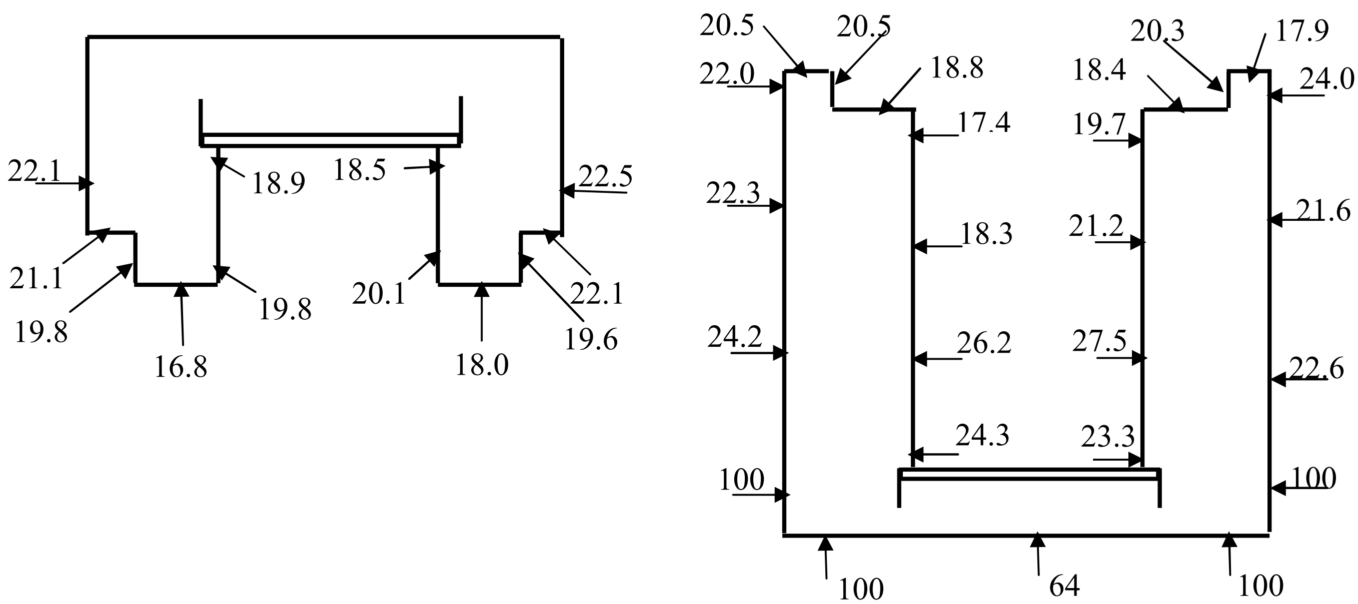


Figure 2. Summary of fiberboard moisture content for 9975-01818. All values are % wood moisture equivalent (%WME).

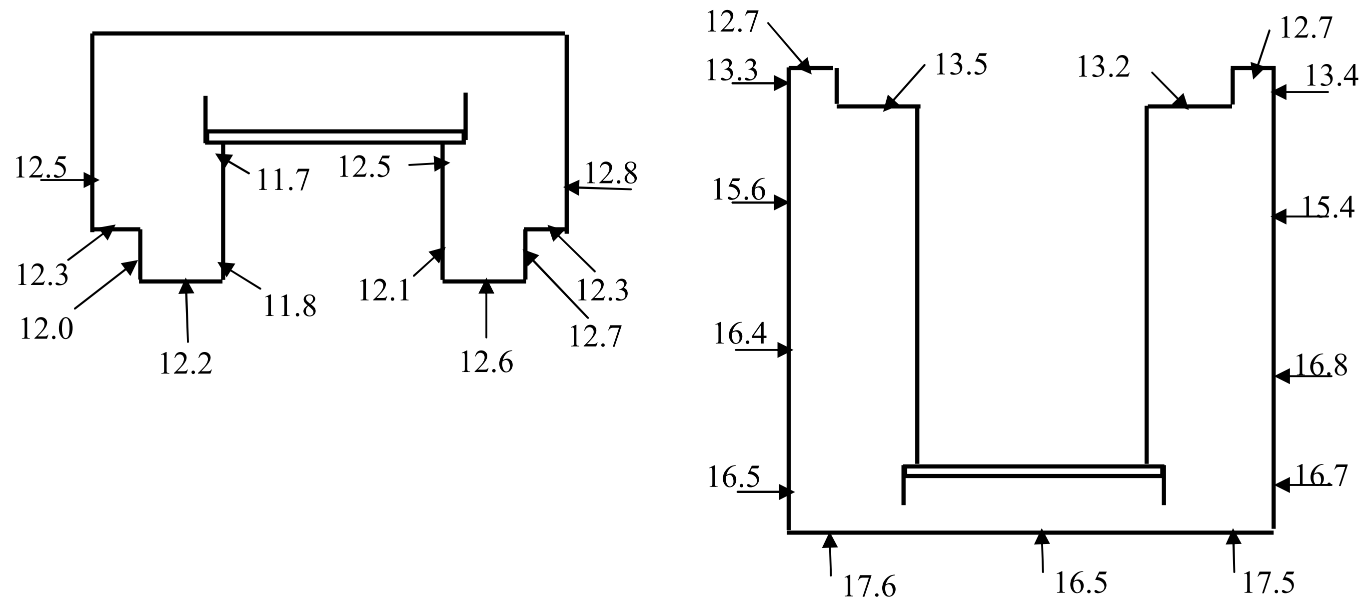


Figure 3. Summary of fiberboard moisture content for 9975-01903. All values are % wood moisture equivalent (%WME). Interior surfaces of the lower assembly were not accessible for measurement.

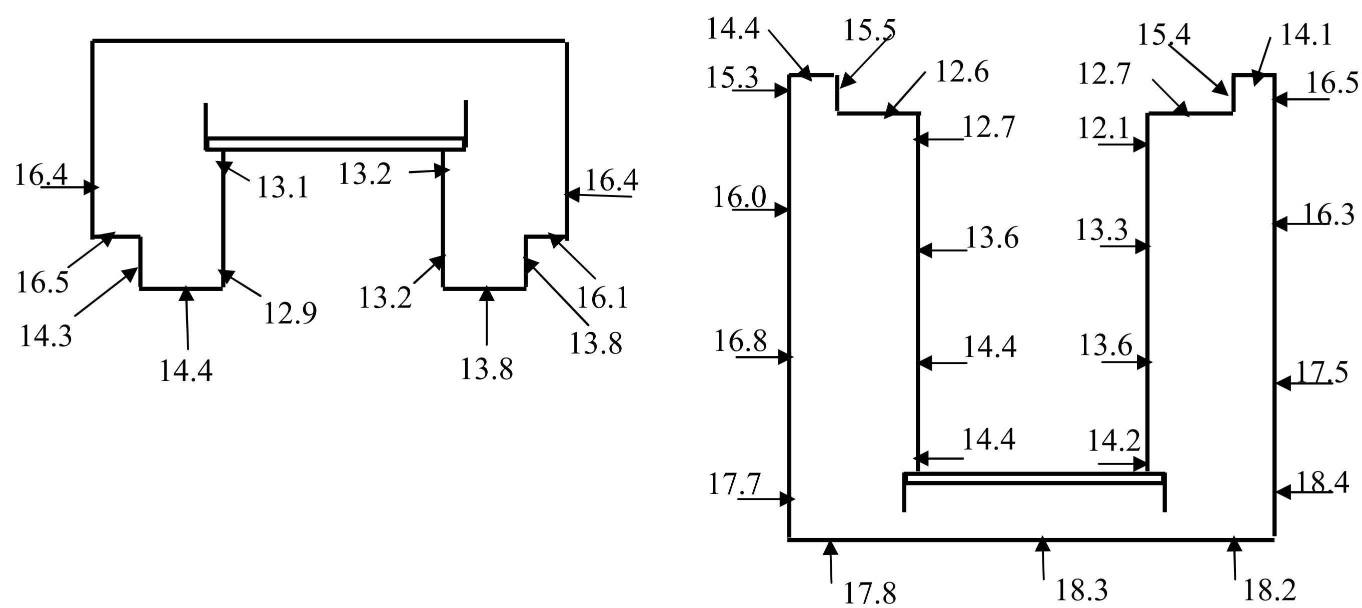
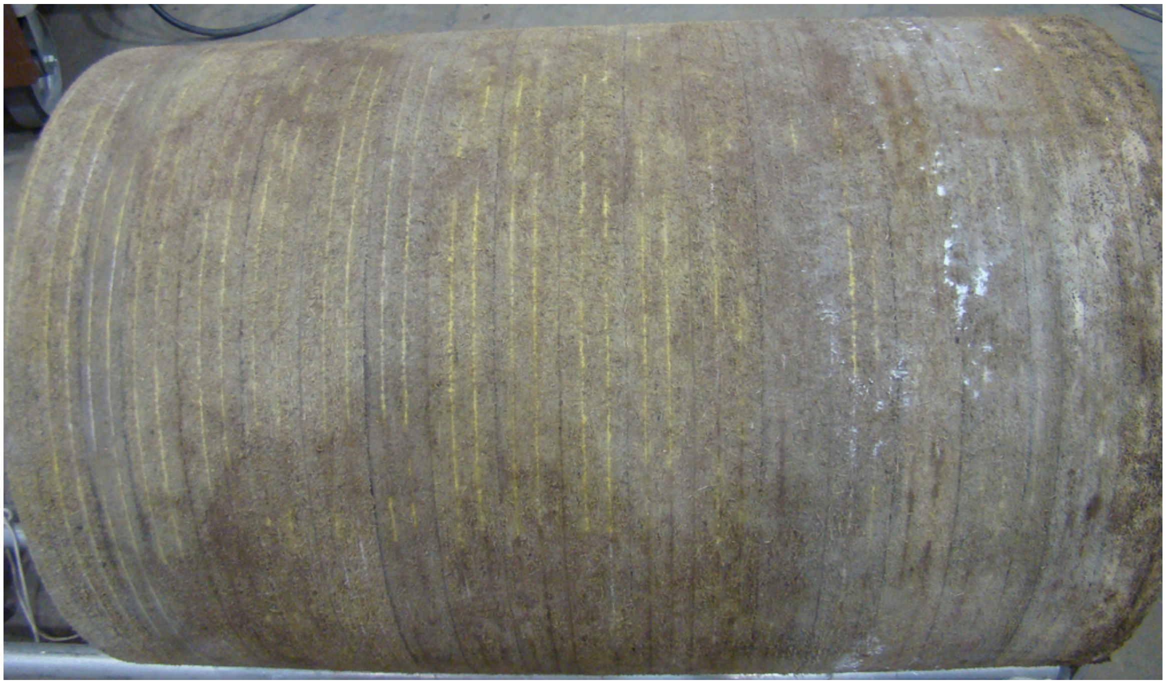
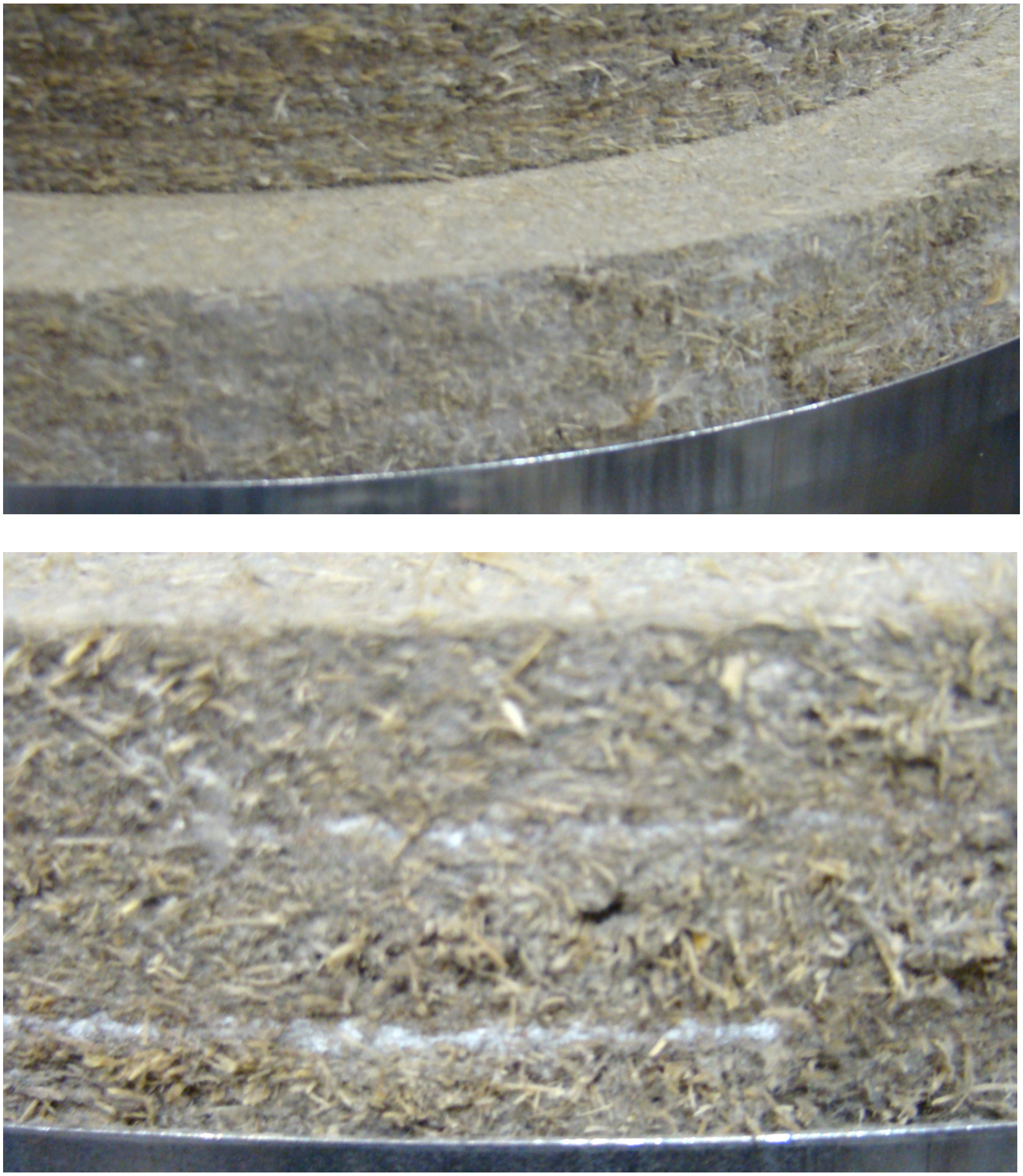


Figure 4. Summary of fiberboard moisture content for 9975-02287. All values are % wood moisture equivalent (%WME).


(a)


(b)

Figure 5. Mold on 9975-01818 lower fiberboard assembly. Photographs provided by NMM (Hackney).



(a) (b)

Figure 6. Mold on 9975-01818 upper fiberboard assembly. Photographs provided by NMM (Hackney).

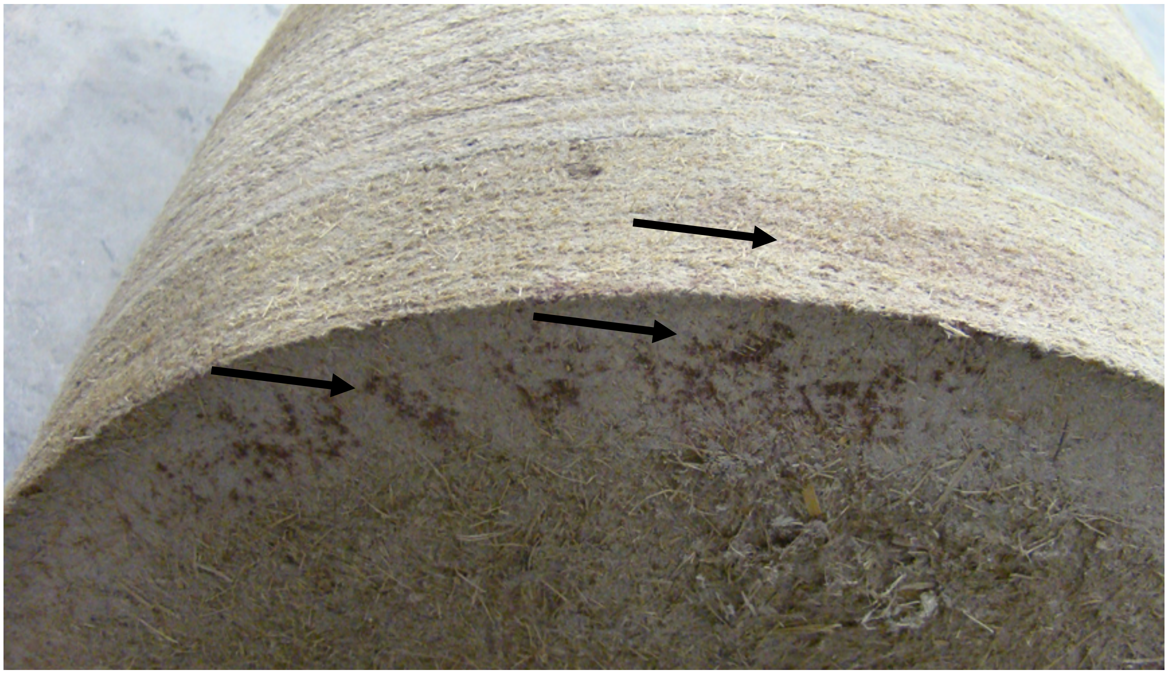
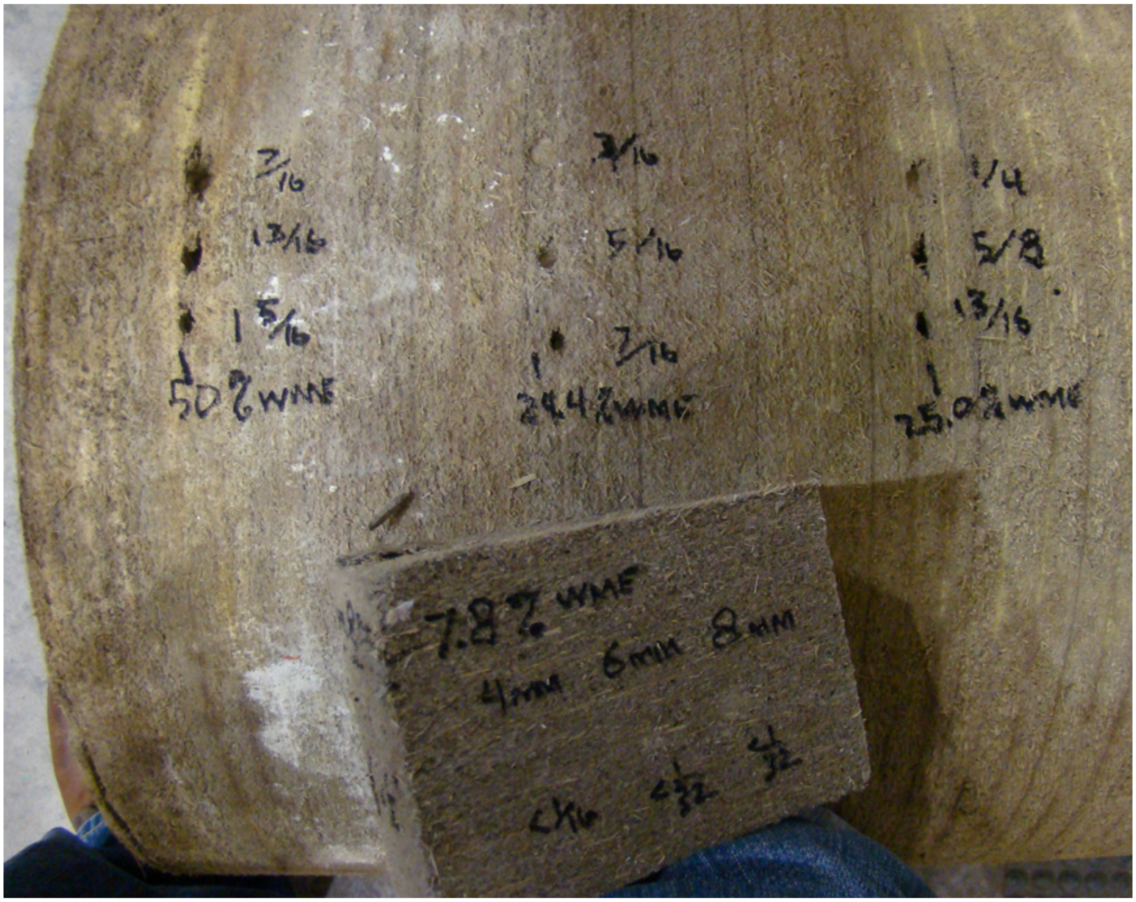


Figure 7. Mold on 9975-01903 lower fiberboard assembly. Photograph provided by NMM (Hackney).

(a) 9975-01818 (b) 9975-01903 (c) 9975-02287

Figure 8. Lead shield from each package showing the relative extent of corrosion. Photographs provided by NMM (Hackney).



(a)

(b)

Figure 9. Lower fiberboard assembly from 9975-01818 after penetration test. The moisture content and depth of penetration are indicated next to each impression.

Figure 10. Band of compression around the bottom of 9975-02287 lower fiberboard assembly.

Figure 11. Compression of the entire bottom of 9975-01818 lower fiberboard assembly, as indicated by the lettering transferred from the drum bottom.

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