EVALUATION EFFECT OF AIR CIRCULATION IN TRAILERS ON MOLD GROWTH

Test Report-No: 2012-0028

Client

Company: Lumber Sales and Production, Inc
Contact Name: Diana Parins
Address:
Phone: T: (262) 677-9033
Email: lumberpallets@sbcglobal.net

Purpose of the Test

Evaluate the effect of ventilation in a shipping trailer to prevent mold on green hardwood pallets

Test Program

Modified ASTM D4445 for full scale specimens

Test Period

09/09/2012 – 10/06/2012

Test Performed By

The Center for Packaging and Unit Load Design,
Virginia Polytechnic Institute & State University,
1650 Research Center Dr, Blacksburg, Virginia 24061.
Phone: (540) 231-7673 Fax: (540) 231-8868 email: lhorvat@vt.edu

Description of Test Methodology

During the study, a ventilated and a non-ventilated trailer were utilized. The ventilated trailer had two fans built in on the front side and vent holes were positioned along the side and at the rare.

Mold Cultures:

Penicillium sp.; Aspergillis sp.; Verticillium sp. species were isolated and cultivated in a petri dish using a 5% acidified potato dextrose agar according to ASTM D4445. To prepare the spore suspension 5ml tap water was added to the petri dish and the surface of the culture was rubbed with a blunt glass rod. The loosened spores then were washed into 1gal bottle. All the three mold species were mixed into the same tank then the water level was adjusted. Altogether, 5gal mixed spore solution was prepared. The solution was kept in an ice cooler until its application.

Pallets:

One thousand and forty (1040) three stringer hardwood pallets (GMA Pallet) were manufactured on September 6, 2012 using green ash, oak, and maple lumber. The moisture content of the pallets was 30% - 39%. The pallets were labeled individually. The numbering systems started from the bottom of each stack located on the left side of the trailer. The pallets were loaded in Jackson, WI and were transported to the Unit Load lab in Blacksburg, VA. The fans did not operate during the trip.

Figure 1 Back and front view of the used three stringer hardwood pallet (GMA Pallet)

Experimental Design

After arrival the pallets were unloaded and ten (10) percent of the pallets were inoculated with the mixed spore solution of *Penicillium sp.; Aspergillis sp.; Verticillium sp*. in Blacksburg, VA on September 9, 2012. The inoculation was conducted by spraying the top deck boards of the pallets with the mold solution. There was no visible mold on the pallets prior to the inoculation. Fully randomized design was used to position the inoculated pallets in the pallet stacks (Figure 2a,b). Then the pallet stacks were organized in a staggered design in the trailers (Figure 2c).

Left Row

Stack 1	Stack 2	Stack 3	Stack 4	Stack 5	Stack 6	Stack 7	Stack 8	Stack 9	Stack 10	Stack 11	Stack 12	Stack 13
20	40	60	80	100	120	140	160	180	200	220	240	260
19	39	59	79	99	119	139	159	179	199	219	239	259
18	38	58	78	98	118	138	158	178	198	218	238	258
17	37	57	77	97	117	137	157	177	197	217	237	257
16	36	56	76	96	116	136	156	176	196	216	236	256
15	35	55	75	95	115	135	155	175	195	215	235	255
14	34	54	74	94	114	134	154	174	194	214	234	254
13	33	53	73	93	113	133	153	173	193	213	233	253
12	32	52	72	92	112	132	152	172	192	212	232	252
11	31	51	71	91	111	131	151	171	191	211	231	251
10	30	50	70	90	110	130	150	170	190	210	230	250
9	29	49	69	89	109	129	149	169	189	209	229	249
8	28	48	68	88	108	128	148	168	188	208	228	248
7	27	47	67	87	107	127	147	167	187	207	227	247
6	26	46	66	86	106	126	146	166	186	206	226	246
5	25	45	65	85	105	125	145	165	185	205	225	245
4	24	44	64	84	104	124	144	164	184	204	224	244
3	23	43	63	83	103	123	143	163	183	203	223	243
2	22	42	62	82	102	122	142	162	182	202	222	242
1	21	41	61	81	101	121	141	161	181	201	221	241

a

Right Row

Stack 1	Stack 2	Stack 3	Stack 4	Stack 5	Stack 6	Stack 7	Stack 8	Stack 9	Stack 10	Stack 11	Stack 12	Stack 13
280	300	320	340	360	380	400	420	440	460	480	500	520
279	299	319	339	359	379	399	419	439	459	479	499	519
278	298	318	338	358	378	398	418	438	458	478	498	518
277	297	317	337	357	377	397	417	437	457	477	497	517
276	296	316	336	356	376	396	416	436	456	476	496	516
275	295	315	335	355	375	395	415	435	455	475	495	515
274	294	314	334	354	374	394	414	434	454	474	494	514
273	293	313	333	353	373	393	413	433	453	473	493	513
272	292	312	332	352	372	392	412	432	452	472	492	512
271	291	311	331	351	371	391	411	431	451	471	491	511
270	290	310	330	350	370	390	410	430	450	470	490	510
269	289	309	329	349	369	389	409	429	449	469	489	509
268	288	308	328	348	368	388	408	428	448	468	488	508
267	287	307	327	347	367	387	407	427	447	467	487	507
266	286	306	326	346	366	386	406	426	446	466	486	506
265	285	305	325	345	365	385	405	425	445	465	485	505
264	284	304	324	344	364	384	404	424	444	464	484	504
263	283	303	323	343	363	383	403	423	443	463	483	503
262	282	302	322	342	362	382	402	422	442	462	482	502
261	281	301	321	341	361	381	401	421	441	461	481	501

b

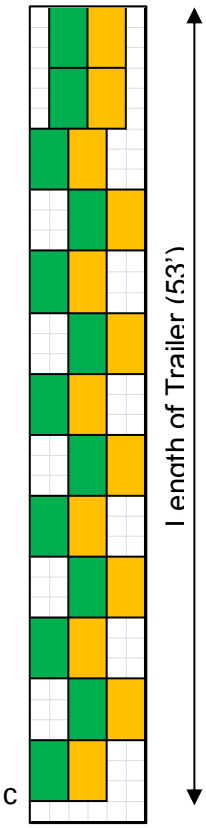


Figure 2 Location of inoculated pallets (a, b), loading pattern of pallet stacks (c) in the trailer.

To monitor the environmental conditions in the trailer, OMEGA Om-40 data loggers were installed at the front and rare of the trailers on the left as well as on the right side. The locations of the data loggers are presented in Figure 3. Temperature, relative humidity and dew point were recorder every 30 min throughout the duration of the study.

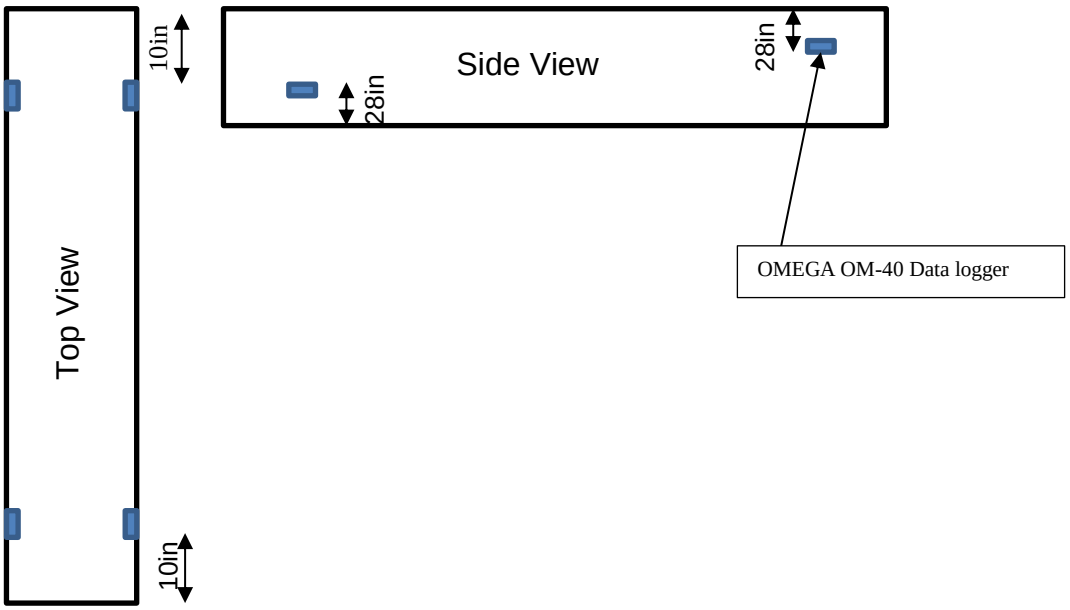


Figure 3 Location of OMEGA data loggers.

The ventilated trailer was connected to the electrical grid of the building and both trailers were kept for 28 days and were opened an unloaded on October 7 (closed trailer) and October 9 (ventilated trailer). The moisture content of the first pallet, 10th pallet, and 20th pallet in the stack were measured using Delmhorst J-2000 wood moisture meter (Figure 4). The level of degradation was determined using the recommendation of ASTM D4445 standard. The categories used for grading is presented in Table 1.

Stack 1	Stack 2	Stack 3	Stack 4	Stack 5	Stack 6	Stack 7	Stack 8	Stack 9	Stack 10	Stack 11	Stack 12	Stack 13
20	40	60	80	100	120	140	160	180	200	220	240	260
19	39	59	79	99	119	139	159	179	199	219	239	259
18	38	58	78	98	118	138	158	178	198	218	238	258
17	37	57	77	97	117	137	157	177	197	217	237	257
16	36	56	76	96	116	136	156	176	196	216	236	256
15	35	55	75	95	115	135	155	175	195	215	235	255
14	34	54	74	94	114	134	154	174	194	214	234	254
13	33	53	73	93	113	133	153	173	193	213	233	253
12	32	52	72	92	112	132	152	172	192	212	232	252
11	31	51	71	91	111	131	151	171	191	211	231	251
10	30	50	70	90	110	130	150	170	190	210	230	250
9	29	49	69	89	109	129	149	169	189	209	229	249
8	28	48	68	88	108	128	148	168	188	208	228	248
7	27	47	67	87	107	127	147	167	187	207	227	247
6	26	46	66	86	106	126	146	166	186	206	226	246
5	25	45	65	85	105	125	145	165	185	205	225	245
4	24	44	64	84	104	124	144	164	184	204	224	244
3	23	43	63	83	103	123	143	163	183	203	223	243
2	22	42	62	82	102	122	142	162	182	202	222	242
1	21	41	61	81	101	121	141	161	181	201	221	241

Moisture content measurement

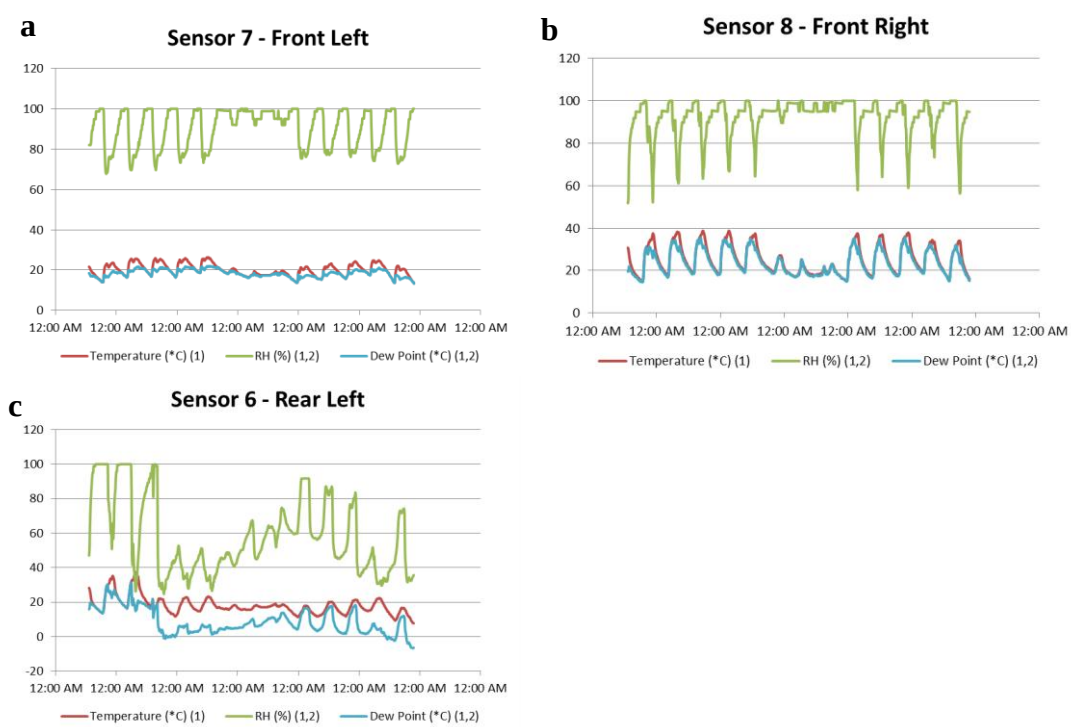
Figure 4 Pallets used the measure the moisture content after unloading

Table 1 Grading levels based on the amount of surface mold

Grades	Amount of Surface Mold
0	0-5%
1	5-20%
2	20-40%
3	40-60%
4	60-80%
5	80-100%

The history of the temperature, relative humidity, and dew point in the non-ventilated trailer is presented in Figure 5. The relative humidity was continuously above 80% and in some nights it exceeded 100%. After opening the trailer condensation on the ceiling and the side wall of the trailer was observed. It is hypothesized that the seal of the door did not work properly during the study because the pallets on the right side of the trailer at the rear were fully saturated and sensor 5 (Rear Left) was defected due to the long term moisture exposure. Meanwhile, on the left side of the trailer at the rear sensor 6 experienced reductions in the relative humidity of the air possibly due to the ventilation effect of the defaulted door seal.

Figure 5 Moisture and temperature history in the non-ventilated trailer



The history of temperature, relative humidity, and dew point for the ventilated trailer is presented in Figure 6. It was found that the utilized fans successfully kept the relative humidity lower than 100% throughout the investigated 28 days.

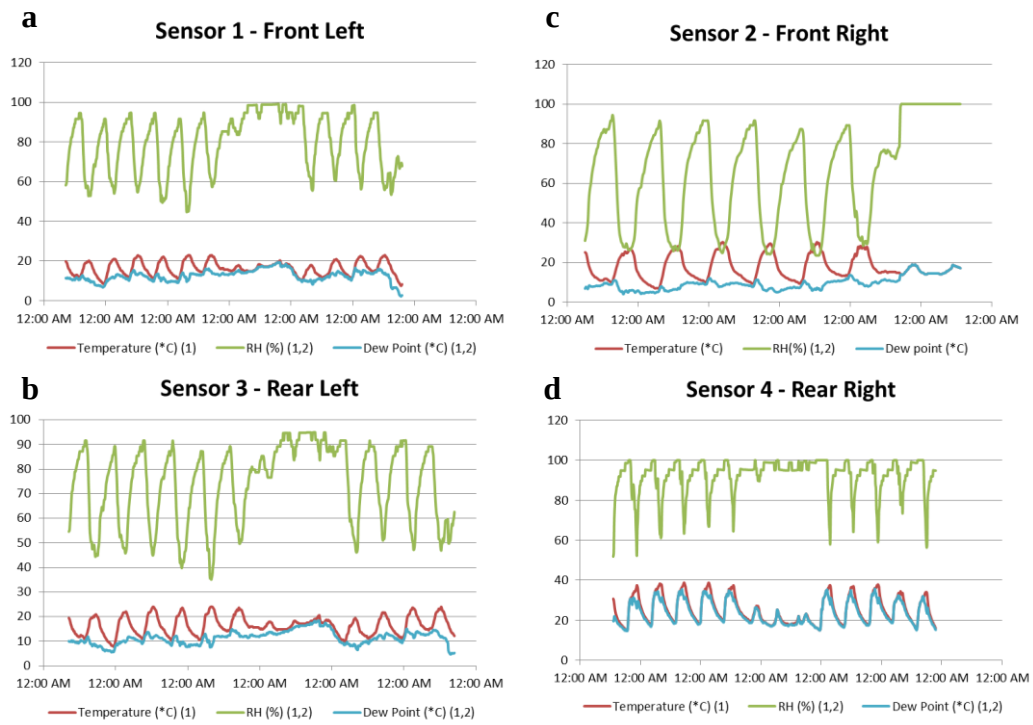


Figure 6 Moisture and temperature history in the ventilated trailer

The moisture content of the bottom, middle, and top pallets were measured for every stack after unloading the samples from the trailer. The summarized result of the moisture content measurement is presented in Table 2. The moisture content of the pallets in the non-ventilated trailer was above the fiber saturation point. While the moisture content of the pallets in the ventilated trailer were below the fiber saturation point.

The moisture content of the pallets located on the top of the stacks were lower than the moisture content of every other pallet which might be due to the increased free air circulation on the top of the stacks. The results of the moisture content measurement are visualized in Figure 7.

Table 2 Summary of the moisture contents of pallet parts after unloading them from the trailers

	Moisture Content (%)					
	Top Deck			Stringer		
	Bottom	Middle	Top	Bottom	Middle	Top
Non-Ventillated Trailer	32.0	34.2	35.5	28.6	29.4	30.8
Ventillated Trailer	15.5	16.9	12.2	14.3	15.1	12.8

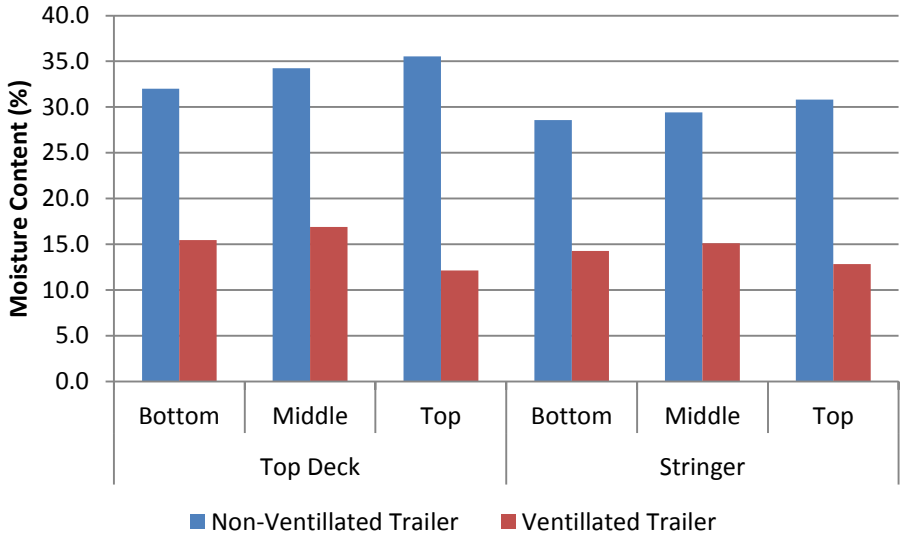


Figure 7 Summary of the moisture contents of pallet parts after unloading them from the trailers

The results of the level of mold degradation of the pallets were summarized in Table 3. Greater mold degradation was found for the pallets in the non-ventilated trailer than for the pallets in the ventilated trailer. The results of the mold degradation were visualized in Figure 9. The pallets in the ventilated trailer were practically mold free.

As expected, further analysis of the results also showed the amount of mold degradation follows the changes in moisture content of the pallet. The amount of mold was reduced close to the top of the stack for the ventilated trailer where the pallets had significantly lower moisture content (Figure 9).

Table 3 Summary of the level of mold degradation

	Level of Mold Degradation			
	Top Deck	**Stringers**	**Bottom Deck**	**Average**
Non-Ventilated Trailer	1.0	0.8	1.4	1.1
Ventilated Trailer	0.1	0.0	0.2	0.1

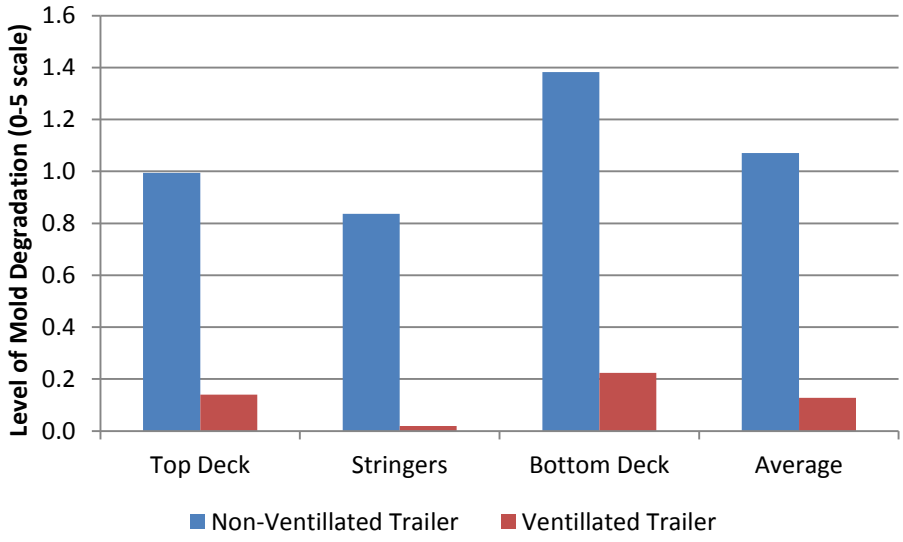


Figure 8 Summary of the level of mold degradation

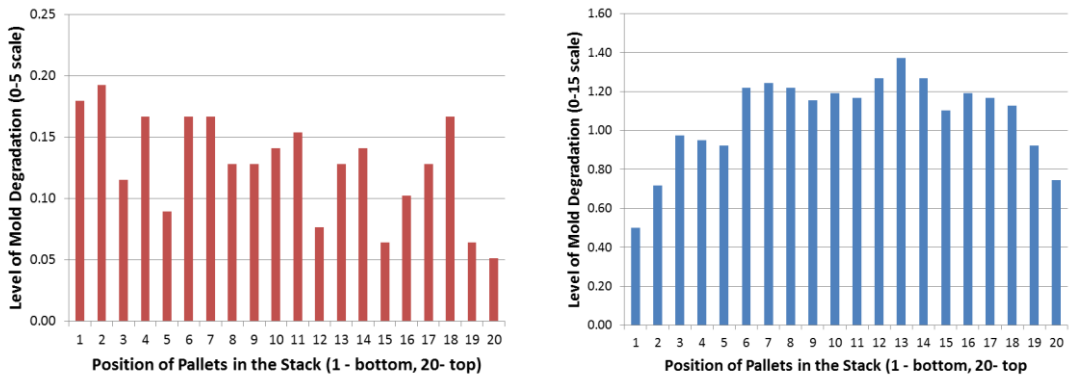


Figure 9 Level of mold degradation by location of the investigated pallets

Representative Pictures of each pallet "grade"

Figure 10 Representative photos of grade 0 (little to no visible mold growth). (A) Top deck boards, (B) Stringers, (C) Bottom deck boards.

Figure 11 Representative photos of grade 1. (A) Top deck boards, (B) Stringer, (C) Bottom deck boards. (Without AFTS installed in trailer)

Figure 12 Representative photos of grade 2. (A) Top deck boards (B) Bottom deck boards (With AFTS installed on trailer)

Figure 13 Representative photos of grade 3. (A) Bottom deck boards (B) Stringer. (Without AFTS installed in trailer)

Summary

The 28 days study verified that the ventilated trailer has a significant effect on the mold growth on green hardwood pallets transported in the physical distribution. The majority of the 520 pallets transported in the ventilated trailer had less than 5% visually observed mold which is considered mold free in any practical application. Contrary pallets in the closed trailer experienced mold on 20-40% of their surface. It needs to be mentioned that the study was conducted in September when the weather was not ideal for mold growth; therefore, in the spring or summer season the difference between the observed mold degradation in the two trailers could be even more significant. In addition to the mold prevention, the continuous ventilation reduced the moisture content of the pallets to12-17%.

Disclamer