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OBSERVATIONS ON THE STORAGE OF GRASS SILAGE

by

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Grass silage has been defined as silage made from any uncured hay or forage crop. Its use has become widespread during the past few years and, as a result, some problems have arisen that require engineering research for solution.

Silo deterioration and failures brought demands from farmers for assistance, and to meet this demand an investigation was instigated at the New Jersey Agricultural Experiment Station in 1937 with the cooperation of the Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, to measure the pressures exerted on silo walls by grass silage. The project has now been expanded to include investigations on juice control, protection of silos from the action of silage acids, and harvesting methods and machinery. This expansion has been materially assisted by a research grant made jointly by the American Steel and Wire Company with the Carnegie-Illinois Steel Company, the National Association of Silo Manufacturers and the Portland Cement Association.

The term "silo failure" as used in the preceeding paragraph has added significance. In the past when a silo failed it burst. Now that leakage is more prevalent, farmers have become juice conscious and are demanding silos that will not leak. The term "failure" then has gained broader meaning and a silo may be said to fail not only if it bursts but also if it leaks, deteriorates or disintegrates. While this definition may not be universally accepted, it does indicate a condition that must be met in silo design.

Juice Control

The juice in grass silage presents a sort of "poly-phase" problem. In high-moisture silage it may, and frequently does, leak or drain from the silo causing offensive odors, damage to any concrete or metal reinforcing over which it flows, and some loss of nutrients. Its control may be approached in several ways. One is to wilt the green crop in the field until its moisture content is lowered to between 65 and 70 per cent. Reports from farmers indicate some success with this method but considerable experience is required to determine when wilting has progressed to the proper stage. Wilting is also dependent on favorable weather, and the introduction of a fair weather factor in the production of grass silage is not desirable.

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- (1) Presented at the Twenty-Eighth Annual Convention, National Association of Silo Manufacturers, Chicago, December 2, and the meeting of the American Society of Agricultural Engineers, Chicago, December 4, 1940.
 - (2) Assistant Agricultural Engineer, New Jersey Agricultural Experiment Station and Assistant Agricultural Engineer, Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, respectively.

A second method is to add to the chopped material some dehydrated preservative such as oat hulls or citrus pulp fortified with molasses to absorb the free moisture. It will be noted in Table I that two silos, L5, 1940 and B1, 1938, were filled using this type of preservative and that there was no leakage even with the high moisture green material. Corn meal and ground ear corn are now being tried as moisture absorbing preservatives. A third method reported as practiced by middle western farmers is to use a longer cut on the chopper when ensiling material of high moisture content. Along this same line, the Papee Machine Company is advising its customers to vary the length of cut with the condition of the green material, suggesting a 1/4 inch for low moisture, 1/2 inch for average, and 1 inch for high moisture. This sounds promising and should be investigated under controlled conditions.

In some instances it may be desirable to rid a silo of free juice. Therefore, considerable thought is being given to drainage systems for silos and to preventing seepage at points other than drains. In 1939 three drains were placed in the walls of two 18 foot silos, B4 and B5, Table I. One of the three drains was a 1.5 inch pipe placed opposite the doorway and flush with the inside wall and foundation. The other two were 2.5 inch pipes placed about 6 inches above the foundation and opposite each other in the wall midway between the first drain and the doorway. One silo was filled with 188 tons of phosphoric acid grass silage and the other was filled with 198 tons of molasses grass silage. The average moisture content of the ensiled material in each case was 68 per cent. The drainage loss from the acid silage was 975 gallons of juice, representing 2.24 per cent by weight of the ensiled material. The drainage from the molasses silage was 3,990 gallons, representing a loss of 9 per cent. A point of particular interest is that all of the juice lost from the silos came through the drains. For 1940, using the same two silos, one was filled with 333 tons of phosphoric acid grass silage and the other with 318 tons of molasses grass silage, moisture content in each case being approximately 77 per cent. The leakage loss from the acid silage amounted to almost 16 per cent, while the loss from the molasses silage was about 18 per cent of the total ensiled weight. The drains functioned but carried only part of the leakage. Most of the loss occurred around the doorway, not unexpected because of the pressure panel construction. Some leakage through the stave joints occurred up to a height of 18 feet in each silo. The joint leakage in 1940 was associated with the higher pressures which amounted to almost twice the values measured in 1939. A rock fill about 3 feet in diameter with drain in the bottom was used in silo B6 in 1940. Filled with 97 tons of phosphoric acid grass silage at 70 per cent moisture, the seepage amounted to approximately one per cent, all coming through the drain. Other types of floor drains and vertical wall drains are to be tried.

The hoops on silos B5 and B8 were tightened to produce a stress in the steel of approximately 18,000 pounds per square inch so that the staves might be held together with some force even after the silos were filled. Preliminary observations indicate that prestressed hoops will limit the leakage through the vertical joints of concrete stave silos but cannot be expected to entirely control the leakage problem because of the irregular joint surface found on concrete staves. Horizontal joint leakage was more noticeable when the vertical joint leakage was reduced. In prestressing hoops, considerable difficulty was encountered in holding the stress on intermediate hoops that do not cross the door opening but are held by spreaders. Faulty design, particularly

on spreaders carrying more than one hoop, has been evident. One common fault has been the reduction of effective area of the spreader strap by rivet holes. Improvements that have been noted include the use of continuous heavy angles along the door opening, instead of spreaders, to which the hoops are attached. The angles are held by heavy rods across the door opening at sufficiently wide intervals so as not to interfere with the removal of silage. Welding to strengthen riveted members is also in evidence.

Plastic calking was placed in most of the horizontal joints of three courses of staves in silo B8 to observe its effectiveness as a joint seal. From this one test the value of the calking may be questioned, as there was a small amount of joint leakage in the bottom two stave courses with little to choose between calked and uncalked joints. In any case, its value must be very pronounced to offset the cost of materials and application.

Coatings

To effectively seal the interior and protect the concrete stave silos, some 24 different coatings have been applied. The materials include asphalts, coal tars, oils, paraffin wax, rubber paints, synthetic resins, special plasters, varnish, and waterproofing. Results to date have not been too promising. It has been difficult to get a lasting bond between the coating and the concrete. Tests of coatings are also underway in tile block silos where difficulty has been experienced in maintaining the mortar joint and in steel silos. More durable mortar must be found for block silos as the types now used disintegrate rapidly and leave the reinforcing exposed to the action of silage acids. This will reduce the area of steel and weaken the silo if allowed to continue.

Considerable work has been done in the past on the strength and durability of concrete and concrete staves and protective coatings for concrete. Probably the most extensive work along this line has been a cooperative project between the United States Department of Agriculture and the Agricultural Experiment Station of the University of Minnesota under the direction of Mr. D. G. Miller. The results of some of these tests pertaining in particular to concrete stave silos were published as Paper No. 1713, Scientific Journal Series of the University of Minnesota. While many means of protecting concrete and mortar from acids have been studied, as yet no substitute for a rich well-proportioned mix has been found.

The Portland Cement Association has cooperated with different state agricultural experiment stations in making studies of various protective coatings for masonry silos. As a result of their work they recommend several coatings that may be effective for from 1 to 5 years. The American Concrete Institute through its committees is also investigating means of prolonging the useful life of silos.

Pressures

The equipment being used to measure pressures in silage was developed by the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, and is described in the Journal of the American Society of Agricultural Engineers for June 1939. Silage pressures have been measured

in 7 silos at the New Jersey Station and one at the Beltsville Research Center of the Department of Agriculture, aggregating 12 tests on grass silage and 7 on corn silage. Readings were taken as each 2 or 2-1/2 foot layer of silage was placed in the silos so that the number of individual panel readings taken during the filling of the various silos ranged from 75 to 150 with additional readings being taken each morning and evening during filling and each day during the settling period. The panels averaged about 4 square feet in area. Results are quite variable as may be seen from Figure 1, which summarizes the lateral pressures. Maximum values for grass silage vary from 159 pounds per square foot in a 12-foot diameter silo with 64 per cent moisture silage at a 25 foot head, to 1189 pounds per square foot in an 18-foot silo, with 77 per cent moisture silage at a 40-foot head. This is a range of from approximately one-half to two and one-half times the pressures commonly considered in silo design, which is 12 pounds per square foot per foot of depth.

Factors that affect the amount of lateral pressure on silo walls, in addition to depth, are the moisture content of the silage and its distribution, the preservative used, the diameter of the silo, the fineness of cut, speed of filling and type of material ensiled. The 12 tests on silo pressures with grass silage that have been run to date show the effect of moisture content and the type of preservative. Figures 2 and 3 show how the pressures in 12 and 14-foot diameter silos increase as the moisture content increases. There are some differences in the type of preservative used in these silos, but since the moisture content varies in each case and there are some differences in the materials ensiled with different preservatives no direct comparisons on the effect of preservatives can be made for these silos. Figure 4 demonstrates the effect of both moisture content and preservative in 18-foot-diameter silos. Curves 2 and 5 show the increase in pressures with molasses silage over the pressures with acid silage given in curves 1 and 4. Since the silos represented by curves 1 and 2, also those represented by curves 4 and 5, were filled simultaneously, the effects of diameter, material and moisture content were eliminated and all the differences can be attributed to the preservative. Similarly the increase in pressure found when comparing curve 1 with 4 and curve 2 with 3 and 5 can be attributed to moisture content. The fact that the curve 2 crosses curve 3 between the 25 and 30 foot levels can be ascribed to the difference in the material ensiled in the two silos and the fact that the silo represented by curve 2 had the bulk of the low moisture material in the bottom part and comparatively high moisture silage on top, while the silo represented by curve 3 was filled with silage of a uniform moisture content throughout.

Capacities

Silo capacity as well as pressure is influenced by moisture, silo size, and fineness of cut. It has been observed that with average moisture grass, taken as 65 to 72 per cent, the smaller or average sizes of silos will hold about the same tonnage of grass as corn. Table I. Those holding a greater total tonnage of grass are about balanced by those holding less. As the moisture content is increased, the total tonnage is increased and vice versa. Silos filled with high moisture grass have held up to 50 per cent greater tonnage than would be expected with ^{normal} corn silage. In each case, however, the variation of the dry matter capacity of the silo is slight.

Summary

Foundation drains show promise of satisfactory operation, particularly when pressures are not excessive.

Vertical joint leakage from concrete stave silos may be controlled to some extent by prestressing the hoops. Joints must be redesigned or provided with seals before general satisfaction can be expected.

Results of the New Jersey tests on coatings for concrete are not at all promising. However, other observations seem to indicate that varnishes and synthetic resin with wood oil vehicles, asphalts, coal tars, and Portland cement washes show promise of giving some satisfaction. In choosing an asphalt or coal tar preparation, care should be taken to select one that has a high melting point in order to minimize sticking of the silage. Some suggestions regarding silo coating are given in Bulletin CP 14 of the Portland Cement Association.

Silos should be adequately reinforced. Tables 8 and 9 in U.S.D.A. Farmers' Bulletin 1820, give reinforcing schedules that are adequate.

Silos with exposed reinforcing are likely to be more satisfactory for storing high moisture silage since such reinforcing can be prestressed, or drawn sufficiently tight when the silo is erected to overcome the effect of the silage pressures, thereby lessening the tendency for cracks to open in the walls. It can also be inspected at will and repairs or replacements easily made when necessary.

Under usual farm conditions the average size silos will hold about the same tonnage of grass as corn.

SILAGE INVESTIGATIONS - GRASS SILAGE DATA (1)

(7)

(2)	(3)	(4)		(5)	(6)	(7)
Size feet	Normal Capacity tons of corn silage	Green Material ensiled, tons	Preservative added		Moisture Content (in silo) %	Settled Depth feet
			kind	lbs./tonnage		
10x25	36	36	none	36	72	
10x25	36	32	none	32	68	
11.6x30.	64	60	Molasses	63	low	
11.6x23.5	61	77	Molasses	80	71	
12x30	68	43	Molasses	49	low	
12x30	68	61	Phos. Acid	62	av.	
12x28	61	48	Molasses & "Silo germ"	49	64	
12x41	104	150	Molasses	159	78	
12x41	104	95	Phos. Acid	97	70	
14x33	105	82	Phos. Acid	83	av.	
inc. 6' pit						

14 x 33	105	79	Molasses	104	83	av.			27			NJ, L1, 1938. Same as 12 above
incl. 6' pit												
14x43.5'	150	106	None		106	66	38.5		36	310, head		U.S.D.A.
incl. 6' pit												
14 x 30	92	62	None		62	54	25		29			U.S.D.A.
14 x 37	122	58	None		58	43	30		33			U.S.D.A.
14 x 41	140	102	None		102	64			37			U.S.D.A.
14 x 42	144	135	Molasses	87	141	71	36		41	520, head		NJ, B8, 1940. Some leakage, approx. 2% loss, cutter set at 1/4" cut
												U.S.D.A.
14 x 43.5	150	106	None		106	67	38		35			
14.3 x 35	118	110	Oat Hulls with 40% Molasses	100	115	74	28		30	581, head		NJ, L5, 1940. No leakage
16 x 41	183	154	Molasses	42	157	low			63			NJ, B7, 1937. Top 10' spoiled. No leakage
16 x 41	183	138	Molasses	100	145	63			54			NJ, B7, 1938. Mature crop. Considerable spoilage
												No leakage.
18 x 31.5	161	188	Molasses	106	198	68	27.5		63	527, head		NJ, B5, 1939. Good silage. 9% seepage loss thru drains.
18 x 32.5	168	186	Phos. Acid	20	188	68	27.5		60	431, head		NJ, B4, 1939. Good silage. 2.24% seepage loss thru drains.
18 x 35	187	180	Citrus Pulp & Mol. Dry	100	189	75 Gr. mat.						NJ, B1, 1938. Top 6' spoiled, rest very good. No leakage.
18 x 40	224	261	Molasses	27	265	av.						NJ, B5, 1937. Poor silage, very offensive odor. Mouldy spots. Leakage at doors.

18 x 40	224	200	Molasses	100	210	low	Mixed Grasses	84		NJ, B5, 1938. Top spoiled, also along sides down 10". No leakage
18 x 40	224	330	Phos. Acid	20	333	77	Alfalfa	77	950, 40" head	NJ, B4, 1940. Severe leakage, approx. 16% loss.
18 x 41	231	308	Molasses	66	318	77	Alfalfa	73	1189, 40" head	NJ, B5, 1940. Severe leakage, approx. 18% loss.
18 x 42	237	332	Molasses	100	349	high	Alfalfa & Clover	80		NJ, B3, 1938. Excellent silage. Severe leakage
18 x 42.5	240	263	Molasses	40	268	72	Oats and Peas	75	801, 42.5" head	NJ, B2, 1937. Good sil- age. Leakage from low 5' about 3 weeks after fill.

Notes

- (1) Messrs. Claude Eby and W. H. Tamm, N. J. Agr. Exp. Sta., assisted in preparing data for table.
- (2) Refers to silo diameter and depth of silage immediately after filling.
- (3) From U. S. D. A. Farmers' Bulletin 1820.
- (4) Low moisture content assumed to be below 65%, average 65-72%, high over 72%.
- (5) 30 days after filling.
- (6) For approximate values, low moisture taken as 60%, average as 68%, high as 77%.
- (7) N. J. cutters set for 1/2" cut except as noted.
All N. J. silos sealed with mulch paper covered with at least a ton of chopped grass.
Spoilage refers to silage unsuitable for feed below seal.

Silo Types

- N. J. B1 to B8 incl. - concrete stave.
- N. J. B9, L5 - steel.
- N. J. L1, L2 - wood with 6' poured concrete pit.
- N. J. L4 - tile stave.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	12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Figure 1.
Silo Pressure Investigations
New Jersey Agricultural Experiment Station and U. S. Department of Agriculture Cooperating

Lateral pressures (lbs. per sq. ft.) are shown at 5 ft. intervals in both corn and grass silage. Different preservatives, moisture contents and silo diameters are given. Supporting data may be found in Table 1, key numbers appearing under "Remarks". Pressures for "Standard" based on empirical value of 12 lbs./sq.ft./ft. of depth.

Figure 2.

Figure 3.

Figure 4.