

Solution to the Problem of Cleaning Out of Silo Floors

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Summary

The author describes the problems associated with the unloading of silos, in particular those for grain storage. The "Matscrew" Silo Unloader is described and significant cost savings are claimed over other unloading methods.

1. Introduction

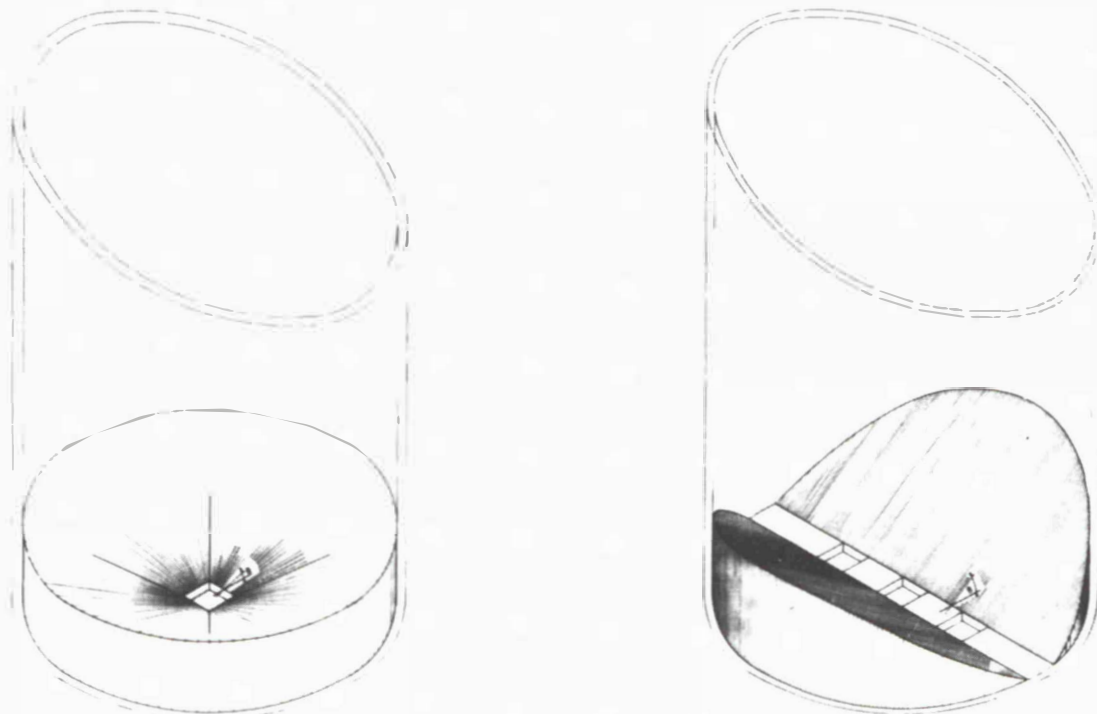
In South Africa's major grain producing areas, every 'dorpie' or village has got one or more grain silos. Besides these there are numerous silos in the manufacturing industry in the industrial areas. Civil engineering-wise, the simplest solution for the construction of a silo is to cast a floor slab with the necessary cast-in frames and then slide the side walls up and cover the silo wall with a conical hat of either concrete or sheet metal.

2. Calculation of Cleaning Costs

Commonly used diameters are: 8.9 m (29 ft); 15.211 m (50 ft) and 18.3 m (60 ft), with larger silos being more popular in more recent times and the trend to larger silos continuing.

We have based all our calculations on a wide range of silo diameters: 10; 12.5; 16; 20; 25; 31.5 and 40 m, to include industrial silos for material other than grain products.

Table 1 indicates the volumes of grain which cannot be discharged by gravity for 'Shape A' and 'Shape B' as in Fig. 1 with one, respectively three outlets. It has to be noted, however, that the three outlet version 'Shape B' is structurally not as safe as 'Shape A', since the structure is laid out normally for symmetrical loads, which will not be the case when an operator decides to open one of the side gates before the silo is empty. Table 2 estimates the required man hours to empty manually the two types of silos. Interesting to note is



Shape A

Fig. 1: Material formation in silos

Shape B

Table 1: Grain retained on a flat silo floor (m³)

DEG	SILO DIAMETER (m) SHAPE A							SILO DIAMETER (m) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
0														
20	91	179	378	743	1459	2931	6022	52	105	226	450	892	1807	3739
21	95	188	399	784	1539	3091	6351	55	111	238	474	941	1906	3943
22	100	198	420	825	1620	3254	6685	58	116	251	499	990	2006	4150
23	106	208	441	867	1702	3418	7023	61	122	263	525	1040	2108	4360
24	111	219	463	909	1785	3585	7367	64	128	276	550	1091	2211	4573
25	116	229	484	952	1869	3755	7715	67	134	289	576	1143	2315	4790
26	121	239	507	996	1955	3928	8070	70	140	303	603	1195	2422	5010
27	127	250	529	1040	2043	4103	8430	73	147	316	630	1249	2530	5234
28	132	261	552	1086	2132	4282	8798	76	153	330	657	1303	2640	5462
29	138	272	576	1132	2222	4464	9171	79	160	344	685	1359	2752	5694
30	144	283	600	1179	2314	4649	9553	83	166	358	713	1415	2867	5930
31	149	295	624	1227	2409	4839	9942	86	173	373	743	1473	2983	6172
32	155	307	649	1276	2505	5032	10339	89	180	388	772	1532	3103	6418
33	162	319	675	1326	2603	5230	10745	93	187	403	803	1592	3224	6670
34	168	331	701	1377	2704	5432	11160	96	194	419	834	1653	3349	6928
35	174	344	727	1430	2807	5639	11585	100	202	435	865	1716	3477	7192
36	181	357	755	1484	2913	5851	12021	104	209	451	898	1781	3607	7463
37	187	370	783	1539	3021	6068	12468	108	217	468	931	1847	3742	7740
38	194	384	812	1595	3132	6292	12927	112	225	485	966	1915	3879	8025
39	201	398	841	1654	3246	6521	13398	116	233	503	1001	1985	4021	8318
40	209	412	872	1713	3364	6757	13884	120	242	521	1037	2057	4166	8619
41	216	427	903	1775	3485	7000	14383	124	250	540	1074	2131	4316	8929
42	224	442	935	1839	3610	7251	14898	129	259	559	1113	2207	4471	9249
43	232	458	969	1904	3738	7509	15429	133	269	579	1152	2286	4630	9578
44	240	474	1003	1972	3871	7777	15978	138	278	599	1193	2367	4795	9919
45	249	491	1039	2042	4009	8053	16546	143	288	621	1236	2451	4965	10272

* DENOTES ANGLE OF REPOSE OF MATERIAL

Table 2: Estimated manhours required to move grain manually (h)

DEG	SILO DIAMETER (m) SHAPE A							SILO DIAMETER (m) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
0														
20	23	56	151	372	912	2308	6022	13	34	94	233	577	1472	3864
21	24	59	160	392	962	2434	6351	14	36	99	246	608	1552	4075
22	25	62	168	413	1012	2562	6685	15	38	104	258	640	1633	4289
23	26	65	176	433	1064	2692	7023	16	40	109	272	673	1716	4506
24	28	68	185	455	1116	2823	7367	17	42	115	285	706	1800	4726
25	29	72	194	476	1168	2957	7715	17	44	120	298	739	1885	4950
26	30	75	203	498	1222	3093	8070	18	46	125	312	773	1972	5177
27	32	78	212	520	1277	3231	8430	19	48	131	326	808	2060	5409
28	33	82	221	543	1332	3372	8798	20	50	137	340	843	2150	5644
29	34	85	230	566	1389	3515	9171	21	52	143	355	879	2241	5884
30	36	89	240	589	1447	3661	9553	21	54	149	369	915	2334	6129
31	37	92	250	613	1505	3810	9942	22	56	155	384	952	2429	6378
32	39	96	260	638	1566	3963	10339	23	58	161	400	990	2526	6633
33	40	100	270	663	1627	4118	10745	24	61	167	415	1029	2626	6894
34	42	103	280	689	1690	4277	11160	25	63	174	432	1069	2727	7160
35	44	107	291	715	1754	4440	11585	26	65	180	448	1110	2831	7433
36	45	111	302	742	1820	4607	12021	27	68	187	465	1152	2937	7712
37	47	116	313	769	1888	4779	12468	28	70	194	482	1194	3047	7999
38	49	120	325	798	1958	4955	12927	29	73	201	500	1238	3159	8293
39	50	124	336	827	2029	5135	13398	30	76	208	518	1283	3274	8596
40	52	129	349	857	2102	5321	13884	31	78	216	537	1330	3392	8907
41	54	133	361	888	2176	5513	14383	32	81	224	556	1378	3514	9228
42	56	138	374	919	2256	5710	14898	33	84	232	576	1427	3640	9558
43	58	143	387	952	2336	5914	15429	35	87	240	597	1478	3770	9899
44	60	148	401	986	2420	6124	15978	36	90	248	618	1531	3904	10251
45	62	153	416	1021	2506	6342	16546	37	93	257	640	1585	4043	10615

* DENOTES ANGLE OF REPOSE OF MATERIAL

Table 3: Required filling on silo floor (m²)

#	SILO DIAMETER (m) SHAPE A							SILO DIAMETER (m) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
20	91	179	378	745	1459	2931	6022	54	109	234	466	923	1869	3864
21	95	188	399	784	1539	3091	6351	57	115	247	491	973	1971	4075
22	100	198	420	825	1620	3254	6685	60	121	260	517	1025	2074	4289
23	106	208	441	867	1702	3418	7023	63	127	273	543	1076	2179	4506
24	111	219	463	909	1785	3585	7367	66	133	286	570	1129	2286	4726
25	116	229	484	952	1869	3755	7715	69	139	300	597	1182	2394	4950
26	121	239	507	996	1955	3928	8070	72	146	314	624	1237	2504	5177
27	127	250	529	1040	2043	4105	8430	76	152	328	652	1292	2616	5409
28	132	261	552	1086	2132	4282	8798	79	159	342	680	1348	2730	5644
29	138	272	576	1132	2222	4464	9171	82	166	356	709	1406	2846	5884
30	144	283	600	1179	2314	4649	9553	86	172	371	739	1464	2964	6129
31	149	295	624	1227	2409	4839	9942	89	179	386	769	1524	3085	6378
32	155	307	649	1276	2505	5032	10339	93	187	402	800	1585	3208	6633
33	162	319	675	1326	2603	5230	10745	96	194	418	831	1647	3334	6894
34	168	331	701	1377	2704	5432	11160	100	201	434	863	1710	3463	7160
35	174	344	727	1430	2807	5639	11585	104	209	450	896	1776	3595	7432
36	181	357	755	1484	2913	5851	12021	108	217	467	930	1842	3730	7712
37	187	370	783	1539	3021	6068	12468	112	225	485	964	1911	3869	7999
38	194	384	812	1595	3132	6292	12927	116	233	502	1000	1981	4011	8293
39	201	398	841	1654	3246	6521	13398	120	242	521	1036	2054	4157	8596
40	209	412	872	1715	3364	6757	13884	124	251	540	1074	2128	4308	8907
41	216	427	903	1775	3485	7000	14383	129	260	559	1112	2204	4463	9228
42	224	442	935	1839	3610	7251	14898	134	269	579	1152	2283	4623	9558
43	232	458	969	1904	3738	7509	15429	138	279	600	1193	2365	4787	9899
44	240	474	1003	1972	3871	7777	15978	143	288	621	1236	2449	4958	10251
45	249	491	1039	2042	4009	8052	16546	148	299	643	1279	2536	5134	10615

Table 4: Minimum cost for filling on silo floor (Rand)

DEG	SILO DIAMETER (m) SHAPE A							SILO DIAMETER (m) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
20	400	900	2000	4100	8300	17400	37000	200	500	1200	2400	5100	10700	23000
21	400	900	2100	4300	8800	18300	39000	200	500	1200	2600	5300	11300	24200
22	500	1000	2200	4500	9200	19300	41100	200	600	1300	2700	5600	11900	25500
23	500	1000	2300	4800	9700	20300	43200	300	600	1400	2900	5900	12500	26800
24	500	1100	2400	5000	10200	21200	45300	300	600	1400	3000	6200	13100	28100
25	500	1100	2500	5200	10700	22300	47400	300	600	1500	3100	6500	13700	29400
26	600	1200	2700	5500	11200	23300	49600	300	700	1600	3300	6800	14300	30800
27	600	1200	2800	5700	11700	24300	51800	300	700	1600	3400	7100	15000	32200
28	600	1300	2900	6000	12200	25400	54100	300	700	1700	3600	7400	15600	33600
29	600	1400	3000	6200	12700	26500	56400	300	800	1800	3800	7700	16300	35000
30	700	1400	3200	6500	13200	27600	58800	400	800	1900	3900	8100	17000	36500
31	700	1500	3300	6800	13800	28700	61100	400	800	2000	4100	8400	17700	37900
32	700	1500	3400	7000	14300	29800	63600	400	900	2000	4200	8700	18400	39500
33	800	1600	3600	7300	14900	31000	66100	400	900	2100	4400	9100	19100	41000
34	800	1700	3700	7600	15500	32200	68600	400	1000	2200	4600	9400	19800	42600
35	800	1700	3900	7900	16100	33400	71300	500	1000	2300	4800	9800	20600	44200
36	900	1800	4000	8200	16700	34700	73900	500	1000	2400	4900	10200	21400	45900
37	900	1900	4100	8500	17300	36000	76700	500	1100	2500	5100	10500	22200	47600
38	900	1900	4300	8800	17900	37300	79500	500	1100	2600	5300	10900	23000	49400
39	1000	2000	4500	9100	18600	38700	82400	500	1200	2600	5500	11300	23800	51200
40	1000	2100	4600	9500	19200	40100	85400	500	1200	2700	5700	11700	24700	53000
41	1000	2200	4800	9800	19900	41500	88500	600	1200	2800	5900	12200	25600	54900
42	1100	2200	5000	10200	20700	43000	91700	600	1300	2900	6100	12600	26500	56900
43	1100	2300	5100	10500	21400	44500	94900	600	1300	3100	6300	13100	27400	58900
44	1200	2400	5300	10900	22200	46100	98300	600	1400	3200	6600	13500	28400	61000
45	1200	2500	5500	11300	22900	47800	101800	700	1400	3300	6800	14000	29400	63200

Table 5: Maximum cost for filling on silo floor (Rand)

DEG	SILO DIAMETER (m) SHAPE A							SILO DIAMETER (m) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
0														
20	1300	2700	6000	12300	25100	52200	111200	700	1600	3600	7400	15300	32100	69000
21	1400	2900	6400	13000	26400	55000	117200	800	1700	3800	7800	16100	33900	72800
22	1500	3000	6700	13700	27800	57900	123400	800	1800	4000	8300	17000	35700	76600
23	1500	3200	7000	14400	29200	60900	129600	900	1800	4200	8700	17900	37500	80500
24	1600	3300	7400	15100	30700	63800	136000	900	1900	4400	9100	18700	39300	84400
25	1700	3500	7700	15800	32100	66900	142400	900	2000	4600	9500	19600	41200	88400
26	1800	3700	8100	16500	33600	69900	149000	1000	2100	4800	10000	20500	43100	92500
27	1900	3800	8500	17300	35100	73100	155600	1000	2200	5000	10400	21400	45000	96600
28	1900	4000	8800	18000	36600	76200	162400	1100	2300	5300	10900	22400	47000	100800
29	2000	4200	9200	18800	38200	79500	169300	1100	2400	5500	11400	23300	49000	105100
30	2100	4300	9600	19600	39800	82800	176400	1200	2500	5700	11800	24300	51000	109500
31	2200	4500	10000	20400	41400	86200	183500	1200	2600	6000	12300	25300	53100	113900
32	2300	4700	10400	21200	43100	89600	190900	1300	2700	6200	12800	26300	55200	118500
33	2400	4900	10800	22000	44800	93100	198400	1300	2900	6400	13300	27300	57400	123100
34	2500	5100	11200	22900	46500	96700	206000	1400	3000	6700	13800	28400	59600	127900
35	2600	5300	11700	23700	48300	100400	213900	1500	3100	6900	14400	29500	61900	132800
36	2700	5500	12100	24600	50100	104200	221900	1500	3200	7200	14900	30600	64200	137800
37	2800	5700	12500	25600	51900	108100	230200	1600	3300	7500	15400	31700	66600	142900
38	2900	5900	13000	26500	53900	112000	238700	1600	3400	7800	16000	32900	69100	148200
39	3000	6100	13500	27500	55800	116100	247400	1700	3600	8000	16600	34100	71600	153600
40	3100	6300	14000	28500	57800	120300	256300	1700	3700	8300	17200	35300	74200	159100
41	3200	6600	14500	29500	59900	124700	265600	1800	3800	8600	17800	36600	76900	164800
42	3300	6800	15000	30600	62100	129100	275100	1900	4000	8900	18500	37900	79600	170700
43	3400	7000	15500	31600	64300	133700	284900	1900	4100	9300	19100	39300	82400	176800
44	3600	7300	16100	32800	66600	138500	295000	2000	4300	9600	19800	40700	85400	183100
45	3700	7600	16700	33900	68900	143400	305500	2100	4400	9900	20500	42100	88400	189600

Table 6: Average cost to replace filled space (Rand)

DEG	SILO DIAMETER (m) SHAPE A							SILO DIAMETER (m) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
0														
20	2200	4400	9400	18500	36400	73200	150500	1300	2600	5600	11200	22300	45100	93400
21	2300	4700	9900	19500	38400	77200	158700	1300	2700	5900	11800	23500	47600	98500
22	2500	4900	10400	20600	40400	81300	167100	1400	2900	6200	12400	24700	50100	103700
23	2600	5200	11000	21600	42500	85400	175500	1500	3000	6500	13100	26000	52600	109000
24	2700	5400	11500	22700	44600	89600	184100	1500	3200	6900	13700	27200	55200	114300
25	2800	5700	12100	23800	46700	93800	192800	1600	3300	7200	14400	28500	57800	119700
26	3000	5900	12600	24800	48800	98100	201700	1700	3500	7500	15000	29800	60500	125200
27	3100	6200	13200	26000	51000	102500	210700	1800	3600	7900	15700	31200	63200	130800
28	3300	6500	13800	27100	53200	107000	219900	1800	3800	8200	16400	32500	66000	136500
29	3400	6800	14300	28200	55500	111500	229200	1900	3900	8600	17100	33900	68800	142300
30	3500	7000	14900	29400	57800	116200	238800	2000	4100	8900	17800	35300	71600	148200
31	3700	7300	15600	30600	60200	120900	248500	2100	4300	9300	18500	36800	74500	154200
32	3800	7600	16200	31900	62600	125800	258400	2200	4400	9600	19300	38200	77500	160400
33	4000	7900	16800	33100	65000	130700	268600	2300	4600	10000	20000	39700	80600	166700
34	4100	8200	17500	34400	67500	135700	279000	2400	4800	10400	20800	41300	83700	173200
35	4300	8500	18100	35700	70100	140900	289600	2500	5000	10800	21600	42900	86900	179800
36	4500	8900	18800	37000	72800	146200	300500	2500	5200	11200	22400	44500	90100	186500
37	4600	9200	19500	38400	75500	151700	311700	2600	5400	11600	23200	46100	93500	193500
38	4800	9500	20200	39800	78300	157200	323100	2700	5600	12100	24100	47800	96900	200600
39	5000	9900	21000	41300	81100	163000	334900	2800	5800	12500	25000	49600	100500	207900
40	5200	10200	21700	42800	84000	168900	347000	2900	6000	13000	25900	51400	104100	215400
41	5400	10600	22500	44300	87100	175000	359500	3100	6200	13400	26800	53200	107900	223200
42	5500	11000	23300	45900	90200	181200	372400	3200	6400	13900	27800	55100	111700	231200
43	5700	11400	24200	47600	93400	187700	385700	3300	6700	14400	28800	57100	115700	239400
44	6000	11800	25000	49200	96700	194400	399400	3400	6900	14900	29800	59100	119800	247900
45	6200	12200	25900	51000	100200	201300	413600	3500	7200	15500	30800	61200	124100	256700

Table 7: Average total cost (Rand)

DEG	SILO DIAMETER (a) SHAPE A							SILO DIAMETER (a) SHAPE B						
	10.0	12.5	16.0	20.0	25.0	31.5	40.0	10.0	12.5	16.0	20.0	25.0	31.5	40.0
20	3100	6300	13500	26800	53200	108000	224600	1800	3700	8000	16200	32500	66600	139400
21	3300	6600	14200	28200	56100	113900	236900	1900	3900	8500	17100	34300	70200	147100
22	3500	7000	14900	29700	59000	119900	249400	2000	4100	8900	18000	36100	73900	154800
23	3600	7300	15700	31200	62000	126000	262000	2100	4300	9400	18900	37900	77700	162600
24	3800	7700	16500	32800	65000	132200	274800	2200	4500	9800	19800	39800	81500	170600
25	4000	8000	17300	34300	68100	138400	287800	2300	4700	10300	20800	41600	85300	178700
26	4200	8400	18100	35900	71300	144800	301000	2400	4900	10800	21700	43600	89300	186900
27	4400	8800	18900	37500	74500	151300	314500	2500	5100	11200	22700	45500	93200	195200
28	4600	9200	19700	39100	77700	157900	328200	2600	5400	11700	23700	47500	97300	203700
29	4800	9600	20500	40800	81000	164600	342100	2700	5600	12200	24700	49500	101400	212400
30	5000	10000	21400	42500	84400	171400	356400	2800	5800	12800	25700	51600	105700	221200
31	5200	10400	22300	44200	87800	178400	370900	3000	6100	13300	26800	53700	110000	230200
32	5400	10800	23100	46000	91300	185500	385700	3100	6300	13800	27800	55800	114400	239400
33	5600	11200	24100	47800	94900	192800	400900	3200	6600	14400	28900	58000	118900	248800
34	5800	11700	25000	49700	98600	200300	416400	3300	6800	14900	30000	60200	123500	258500
35	6000	12100	25900	51600	102300	207900	432200	3500	7100	15500	31200	62500	128200	268300
36	6300	12600	26900	53500	106200	215700	448500	3600	7300	16100	32400	64900	133000	278400
37	6500	13000	27900	55500	110100	223700	465200	3700	7600	16700	33600	67300	137900	288700
38	6800	13500	28900	57500	114200	232000	482300	3900	7900	17300	34800	69800	143000	299400
39	7000	14000	30000	59600	118400	240400	499900	4000	8200	17900	36100	72300	148200	310300
40	7300	14500	31100	61800	122600	249100	518000	4100	8500	18600	37400	75000	153600	321500
41	7500	15000	32200	64000	127100	258100	536600	4300	8800	19200	38700	77700	159100	333100
42	7800	15600	33400	66300	131600	267300	555800	4500	9100	19900	40100	80400	164800	345000
43	8100	16100	34600	68700	136300	276900	575600	4600	9400	20600	41500	83300	170700	357300
44	8400	16700	35800	71100	141100	286700	596100	4800	9800	21400	43000	86300	176800	370100
45	8700	17300	37100	73700	146200	296900	617300	5000	10100	22100	44600	89300	183100	383200

that normally this type of work will have to be done with casual labour with overtime etc. The cost is therefore then probably considerably higher than normal labour rates and the work involved may have to be repeated several times a year. To avoid this amount of labour, one solution is to form inside the silo inverted cones or wedges to allow all material to flow by gravity from the silo. Again with grain this is not very difficult, though possibly a costly alternative. Table 3 gives an indication of the quantity of back fill material (mass concrete or compacted soil and concrete etc.) depending on the site location, the system selected etc. Tables 4 and 5 indicate the cost involved. Due to the back filling part of the silos, holding capacity is lost at an average of R25.00/m³ which has to be reinvested somewhere else to maintain storage capacity (see Table 6).

3. The "Matscrew" Silo Unloader

An average total of both construction and space replacement cost reflecting today's building prices, is indicated in Table 7. If this table is compared with Table 8 one can easily see that for most cases it is not just simpler, but also much more economical to use a flat bottom silo with one outlet (no operator errors) and a "Matscrew" Silo Unloader, which allows every flat bottom silo to be converted into a self-cleaning silo without doing any civil engineering work. This machine was developed in conjunction with Robert Leslie & Partners, Cape Town, who have wide experience in building concrete structures.

The design of the machine allows for a maximum vertical pressure of 150 kN/m² which will cover most silos in South Africa. The silo floor will have to carry every 500 mm a load of 18.75 kN instead of the normal grain loading. See Fig. 2 and Table 9 for details.

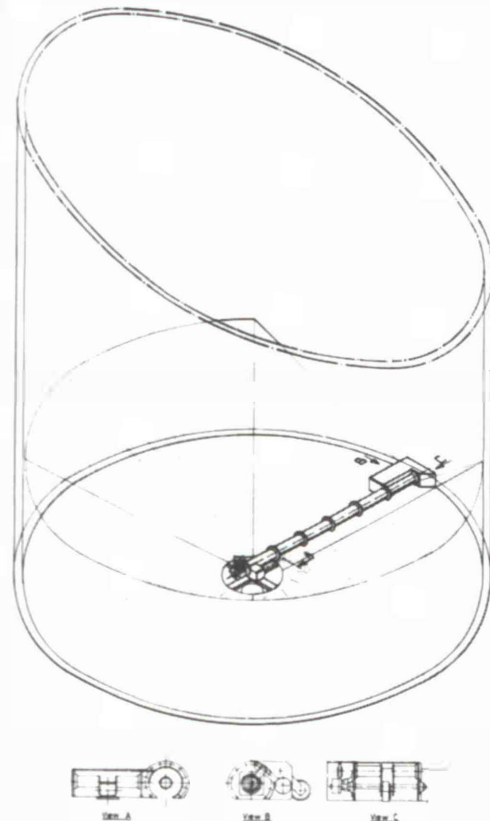


Fig. 2: The "Matscrew" Silo Unloader

Table 8: Estimated cost for a 'Matscrew' Screw Unloader (Rand)

Flat Bottom Silo Diameter (m)						
10.0	12.5	16.0	20.0	25.0	31.5	40.0
7900	8900	10200	11800	13700	16200	19600

Table 9: "Matscrew" Silo Unloader

Up to 8 m:	Installed kW 5.5
Rot. speed:	± 180 rpm
Capacity:	40 t/h ... 70 t/h max.
Diameter	250/240/89
Pitch:	240
Mass:	680 kg
Support load in centre:	4000 N
outside:	2800 N
Propwheel shaft torque max:	160 Nm
Propelling speed:	11 ... 18 m/h
Second moment of area around horizontal axis:	22.1 x 10 ⁻⁶ m ⁴
Second moment of area around vertical axis	16.7 x 10 ⁻⁶ m ⁴

With a drive within the silo, we have avoided potential bearing and power transmission problems posed by an external drive. The motor/gearbox combination is mounted with a hollow shaft (no coupling) straight onto the main shaft, bolted on with an end-shaft washer. The whole unit is supported on rubber springs, whose function is not affected by grain deposits. The forward movement is produced by an eccentric drive which, over a backstop, turns the shaft in one direction only. To prevent the propwheel from slipping a torque limiter is installed.

A second execution requires a pipe diameter of 110 mm to be cast in the centre of the silo which serves as a guide as well as to fit the drive shaft through to the gearbox, which is shaft-mounted. The motor is then accessible from the reclaim tunnel.

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