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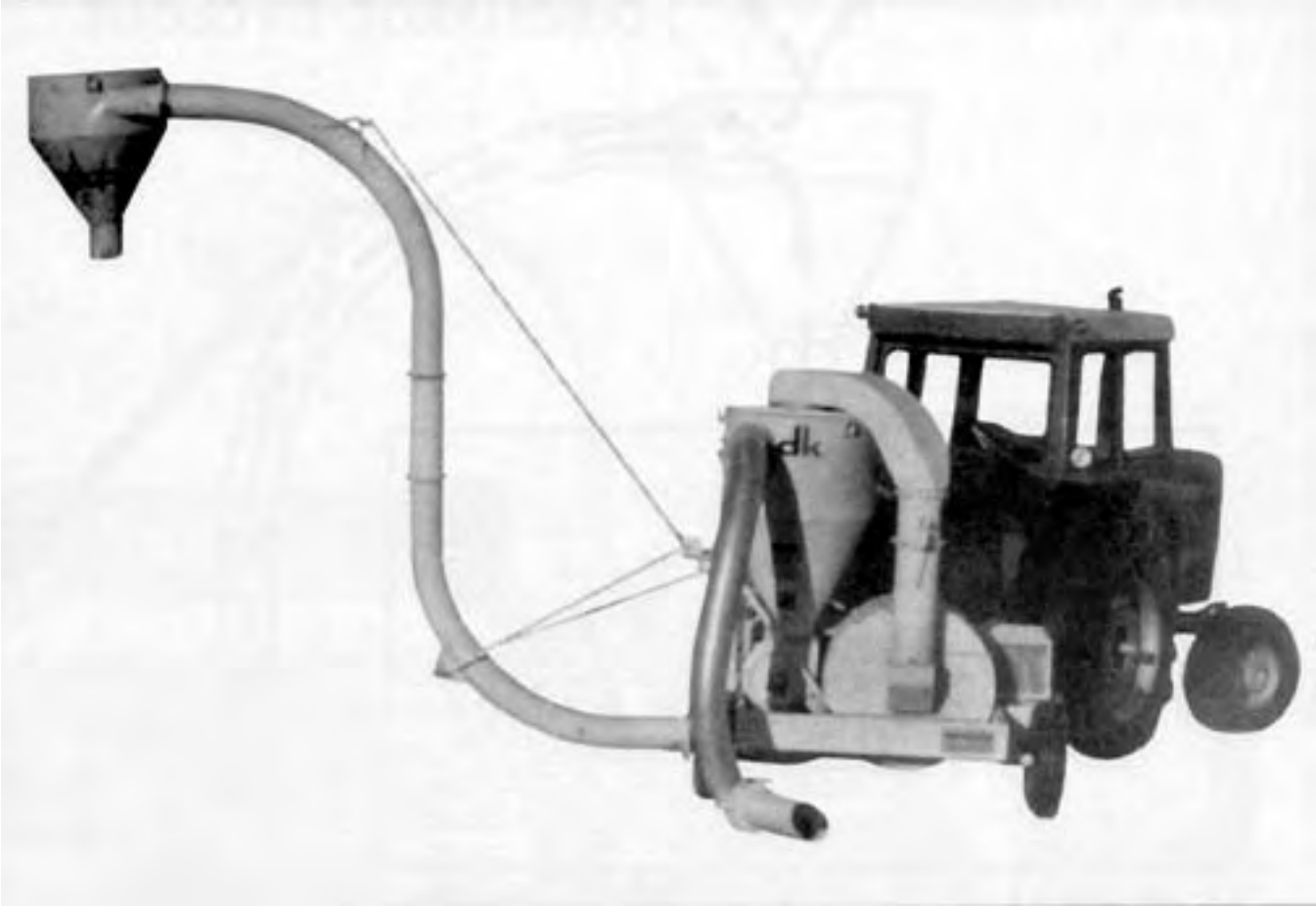

Tractor-Vac Model 9481 (Vac-U-Vator) Pneumatic Grain Conveyor

A Co-operative Program Between
ALBERTA FARM MACHINERY RESEARCH CENTRE
PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

Tractor-Vac Model 9481 (Vac-U-Vator) Pneumatic Grain Conveyor

Manufacturer:
Dunbar Kapple Incorporated
100 North Island Avenue
Batavia, Illinois 60510
U.S.A.

Distributor:
Lee and Backes Incorporated
Glenburn, North Dakota 58740
U.S.A.

Retail Price:
$8,000.00 (f.o.b. Lethbridge, Alberta effective January 1977)

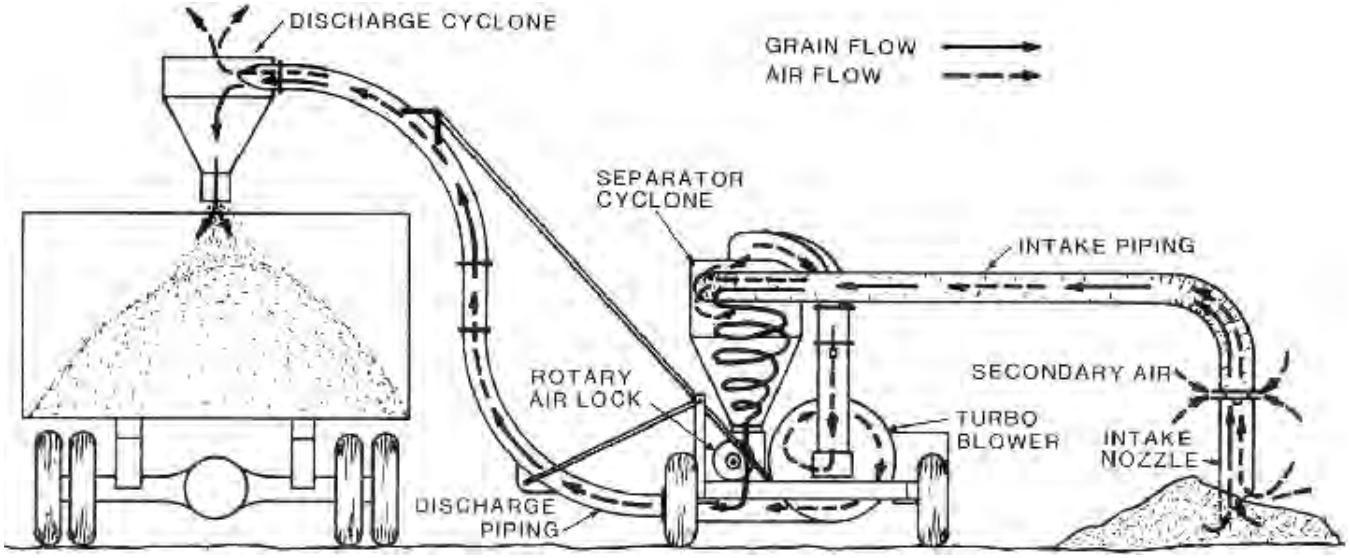

Figure 1. Schematic View of the Tractor-Vac 9481 Showing Air and Grain Flow.

Summary and Conclusions

The functional performance of the Tractor-Vac model 9481 pneumatic grain conveyor was fair for conveying wheat and barley and good for conveying oats. Functional performance was lowered by high power consumption and low conveying rates.

The maximum conveying rates obtained were 27.7 t/h (1015 bu/h) for wheat, 26.7 t/h (1225 bu/h) for barley and 36.9 t/h (2390 bu/h) for oats. Conveying rates were reduced significantly when the intake nozzle was totally submerged in grain or when the intake or discharge pipe length was increased.

Average power requirements while conveying grain varied from 41 kW (55 hp) for wheat and barley to 47 kW (63 hp) for oats. A tractor with power take-off output of at least 60 kW (80 hp) was required due to high starting torque and for unplugging.

The specific capacity of a six inch grain auger was 12 times greater than the Tractor-Vac when conveying wheat, 11 times greater when conveying barley and nine times greater when conveying oats, indicating that pneumatic conveying of grain is very costly and inefficient when compared to a grain auger.

Crackage in dry wheat was about 0.25% for each pass through the Tractor-Vac. This is similar to damage caused by a grain auger.

The intake nozzle was heavy and difficult to maneuver during operations such as cleaning grain bins. Mounting the discharge cyclone on either the standard discharge or mobile discharge cart was difficult and inconvenient. Extra assistance such as a tractor mounted front end loader or equivalent was needed.

The Tractor-Vac was much safer to use than a grain auger, especially for cleaning grain bins. In addition, it could be beneficial to people with grain dust allergies when cleaning bins.

The operator's manual instructions on nozzle use and adjustments were incorrect for the production nozzles now in use.

Recommendations

It is recommended that the manufacturer consider:

1. Revising the operator's manual to state that to obtain maximum flow rates and steady state conveying, an air space should be left at the nozzle inlet.
2. Supplying complete instructions for the optional mobile discharge cart, describing the assembly and use of various elbows to obtain different discharge heights.
3. Modifications to permit the air regulator valve to be locked in the closed position to reduce starting torque.
4. Supplying a slow moving vehicle (SMV) sign to comply with provincial safety regulations.

Chief Engineer: E.O. Nyborg
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Project Engineer: T.T. Nakagawa

The Manufacturer States That

With regard to recommendation number:

1. A new manual is now being written which will show the correct use of all nozzles as well as more detailed information on maintenance.
2. Instructions are available and should have been supplied with the mobile discharge cart.
3. The air regulator has been revised to include a clip, which allows it to be closed for start-up.
4. A slow moving vehicle sign is now supplied as standard equipment.

General Description

The Tractor-Vac 9481 is a 1000 rpm power take-off operated pneumatic grain conveyor mounted on a two wheel trailer. The turbo blower (Figure 1) provides both suction and discharge air to convey grain without passing it through the blower. Grain is conveyed from the intake nozzle to the rotary air lock at the base of the separator cyclone. Grain falls through the air lock into the discharge air stream, which conveys it to the discharge cyclone.

The blower is driven from the power take-off shaft through a multiple V-belt drive, while the rotary air lock is belt and chain driven.

Intake and discharge locations can be varied by adding elbows and sections of rigid and flexible pipe.

Complete specifications are found in Appendix I.

Scope of Test

The Tractor-Vac 9481 was used for 20 hours to convey about 270 tonnes (9900 bu) of wheat, 93 tonnes (4275 bu) of barley and 41 tonnes (2650 bu) of oats. It was evaluated for ease of operation, capacity, power requirements, grain damage and safety.

Results And Discussion

EASE OF OPERATION

Standard Discharge: The standard discharge assembly (Figure 2) consisted of two 90° elbows coupled with a 610 mm (2 ft) rigid pipe. This assembly was designed primarily for conveying grain from a bin to a truck. Neither the reach nor the height were sufficient for filling grain bins. The discharge height was 3200 mm (10.5 ft) and the horizontal reach 1676 mm (5.5 ft).

The discharge cyclone had to be removed and reattached whenever a different configuration of discharge pipe was required. It should also be removed when transporting the Tractor-Vac long distances. The discharge cyclone weighed 34 kg (75 lb) making it difficult to attach and remove.

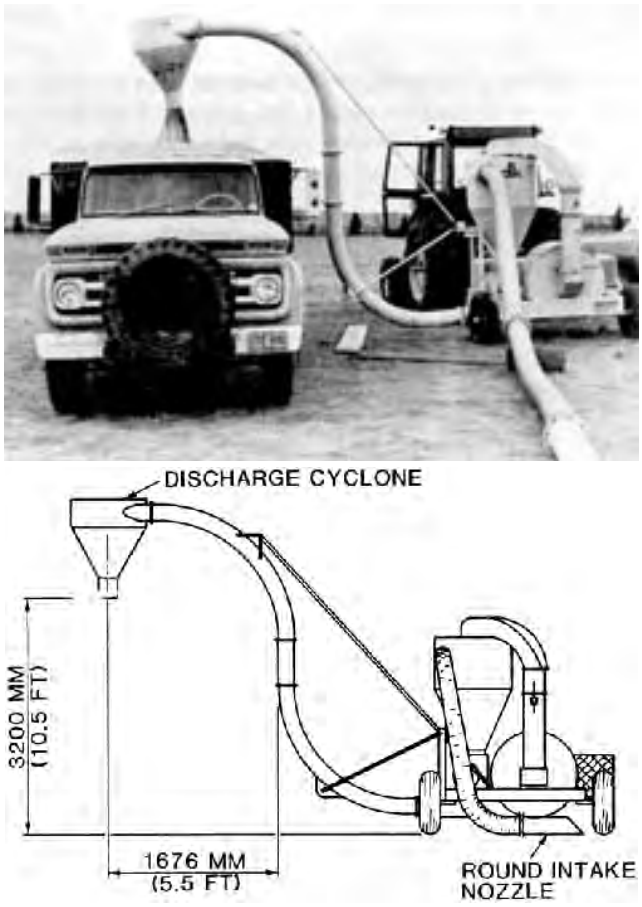


Figure 2. Standard Discharge Assembly.

Mobile Discharge Cart: Discharge height and reach changes could be facilitated by using the optional mobile discharge cart to support the necessary elbows, rigid or flex pipes and discharge cyclone. The discharge cart assembly (Figure 3) provided a height of 5486 mm (18 ft) and a horizontal reach of 5029 mm (16.5 ft). The tube and elbow assembly shown in Figure 3, which placed the discharge 12,497 mm (41 ft) away from the Tractor-Vac, was the most workable for filling bins. This required a total pipe length of 18,288 mm (60 ft). It was difficult and dangerous to elevate and attach the discharge cyclone to the top of the mobile discharge assembly. The discharge cart could be tilted so the cyclone could be attached on the ground. Due to the weight of the cyclone at the end of the discharge, it was difficult to place it back into operating position.

Initial assembly of the mobile discharge cart was inconvenient since the telescoping brackets had to be positioned by trial and error until the correct geometry was obtained. To facilitate assembly, position markers should be shown on the pipe for various lift heights, or detailed assembly instructions should be supplied.

No provision was made for towing the mobile discharge cart assembly, making it necessary to disassemble it for transport. Alternatively, a suitable hitch would have to be fabricated.

Figure 3. Mobile Discharge Cart.

Conveying Pipes: Rigid pipe sections were available in 2438 mm (8 ft) lengths while 3048 mm and 4267 mm (10 and 14 ft) lengths of flexible pipe were available to vary inlet and discharge distances. Adjacent pipes were joined either with three bolts or with quick clamps. Rubber gaskets were used to seal pipe connections. Large radius elbows also were available to change flow direction. Individual pipe sections or elbows each weighed about 14 kg (31 lb). Pipe sections could be joined on level ground by one man. Additional manpower was needed to install assembled pipe up the side of a bin or silo.

Intake Nozzles: Two types of intake nozzles (Figure 4) were available. The round nozzle was used wherever possible for conveying grain. The fiat nozzle was primarily used for bin cleanout. Both the flat and round intake nozzles were difficult to maneuver by one person in a grain bin or truck box. This was due to the combined weight of the nozzle and attached piping, the bending resistance of attached flexible piping and insecure footing when standing in grain.

Figure 4. Two Types of Intake Nozzles.

Although either nozzle could be used to completely empty a grain bin, the labour required to shovel grain to the nozzle was often found to be less than moving and holding the nozzle by hand.

Transport: The standard discharge assembly could be folded into transport position (Figure 5) by one man in less than 10 minutes. Wrenches were required. The Tractor-Vac could be towed at speeds up to 32 km/h (20 mph). Care was needed on rough roads since the centre of gravity of the Tractor-Vac was 1029 mm (40.5 in) above the ground and offset from the wheel centre line (Appendix I). The standard discharge assembly should be removed when transporting long distances at speeds of 32 km/h (20 mph).

Figure 5. Transport Position.

Adjustments: Drive belt tension was easily adjusted. Correct positioning and adjustment of the counterweight on the automatic air regulator (Figure 5) had to be determined by trial and error until the air valve remained fully open when conveying grain at a steady rate. Once the optimum setting had been found, no further adjustment was required for other types of grain.

Secondary air flow into the intake nozzle could be varied by placing spacers between the intake nozzle and intake pipe (Figure 4). Optimum air flow for maximum conveying rates had to be determined by trial and error as no instructions were supplied. Optimum spacing was found to be about 9 mm (0.375 in) for all grains.

Lubrication: The Tractor-Vac 9481 was easy to lubricate as there were only 11 lubrication points.

CAPACITY

Maximum Conveying Rates: Conveying rates for the Tractor-Vac depended on the method of grain intake, type of grain being conveyed, height of discharge and length of intake and discharge piping.

The conveying rate was very dependent on maintaining a steady flow rate. A steady flow rate was difficult to achieve while cleaning a bin. The highest flow rates were obtained with the nozzle not buried in grain but rather, with a space left for air entrance (Figure 6). Completely burying the nozzle (Figure 7) reduced the conveying rate in wheat from 27.7 t/h (1015 bu/h) to 21.8 t/h (800 bu/h). Maximum flows were obtained when the intake was adjusted and positioned as described above and with one length of flex inlet pipe and the standard discharge assembly (Figure 2). As shown in Table 1, maximum conveying rates were 27.7 t/h (1015 bu/h) in wheat, 26.7 t/h (1225 bu/h) in barley and 36.9 t/h (2390 bu/h) in oats. The wide range of capacities shown in Table 1 indicates the difficulty in maintaining constant conditions at the inlet nozzles.

The limiting factor when conveying wheat and barley was the volume of air flow. The maximum volume of air flow could not carry any more grain. The limiting factor when conveying oats was the capacity of the rotary air lock. The quantity of oats dropping from the discharge cyclone was so great that the rotary air lock became overloaded.

Figure 6. Intake Nozzle showing Air Space Required for Obtaining Maximum Conveying Rates.

Effect of Pipe Length: Conveying rates were reduced as the length of intake pipe was increased due to increased friction losses. For example, increasing the intake length from 43 m (14 ft) to 305 m (100 ft), as shown in Figure 8, decreased the maximum conveying rate in wheat from 27.7 t/h (1015 bu/h) to 12.3 t/h (450 bu/h). Increasing the intake length from 4267 mm (14 ft) to

15,240 mm (50 ft) in barley resulted in a decrease in conveying rate from 26.7 t/h (1225 bu/h) to 23.1 t/h (1 060 bu/h).

Figure 7. Intake Nozzle Buried in Grain Resulting in Reduced Conveying Rates.

Increasing the length of discharge piping also reduced the conveying rate due to increased pipe friction. The minimum length of discharge piping when using the mobile discharge cart was 183 m (60 ft). Increasing the length to 305 m (100 ft), as shown in Figure 9, decreased the conveying rate in wheat from 19.9 t/h (730 bu/h) to 16.0 t/h (620 bu/h).

Plugging: The conveying rate could be appreciably reduced if grain built-up in a low spot in the piping. If grain intake was continued with this condition, eventual plugging of the pipe occurred. The Tractor-Vac could usually be unplugged by discontinuing grain intake and allowing the air to clear the blockage. A compromise between increased conveying rate and plugging had to be determined by trial and error.

Comparison to a Grain Auger: Table 2 compares the performance of the Tractor-Vac 9481 to that of a 9753 mm (32 ft) long, 152 mm (6 in) diameter grain auger at 25°, lifting 3962 mm (13 ft). Data for the Tractor-Vac is with the standard discharge assembly (Figure 2) lifting 3200 mm (10.5 ft). As shown, the maximum conveying rate for the Tractor-Vac was 33% less than the grain auger in wheat, 13% less than the grain auger in barley and 53% greater than the grain auger in oats. Much more power was required for the Tractor-Vac in all grains. The specific capacity can be used to compare the conveying efficiency of the two methods. Specific capacity is a measure of the amount of grain conveyed in one hour with one unit of power (one kilowatt or one horsepower). High specific capacity represents efficient energy use while low specific capacity represents inefficient conveying. The specific capacity of the six-inch grain auger was 12 times greater than that of the Tractor-Vac in wheat, 11 times greater in barley and nine times greater in oats. It must be concluded that pneumatic conveying is very costly and inefficient when compared to a grain auger.

Figure 8. Inlet Length of 30,480 mm (100 ft).

Table 2. Comparison of the Tractor-Vac 9481 to a 152 mm (6 in) Diameter Grain Auger

Grain Type	Maximum Conveying Rates				Specific Capacities			
	Tractor-Vac		6-inch Auger*		Tractor-Vac		6-inch Auger*	
	t/h	bu/h	t/h	bu/h	t/kW-h	bu/hp-h	t/kW-h	bu/hp-h
Wheat	27.7	1015	41.5	1520	0.68	18.5	8.27	225
Barley	26.7	1225	30.8	1415	0.65	22.0	7.34	250
Oats	36.9	2390	24.1	1560	0.79	38.0	7.07	340

*The grain auger data were obtained from Agricultural Machinery Administration test report number 1860.

Table 1. Conveying Rates of Tractor-Vac 9481 at 1000 rpm Power Take-Off Speed

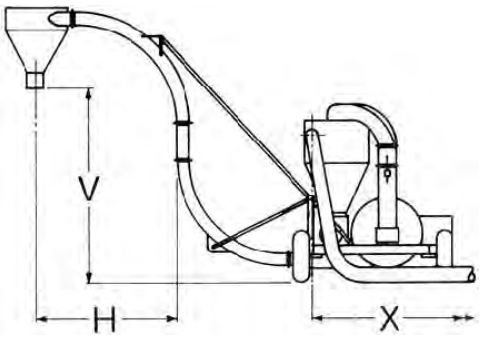
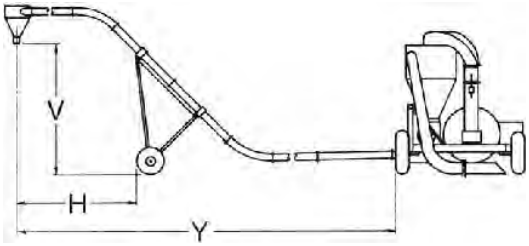
	With Standard Discharge Assembly (Figure 2) and Various Intake Pipe Lengths Lift (V) = 3200 mm (10.5 ft) Reach (H) = 1676 mm (5.5 ft) 			With Mobile Discharge Cart (Figure 3) and Various Discharge Pipe Lengths Lift (V) = 5486 mm (18 ft) Reach (H) = 5029 mm (16.5 ft) 	
	Intake Piping Length (X)			**Discharge Piping Length (Y)**	
Grain Type	**43 m (14 ft)**	**152 m (50 ft)**	**305 m (100 ft)**	**183 m (60 ft)**	**305 m (100 ft) Type**
Wheat	21.8 t/h (800 bu/h) to 27.7 t/h (1015 bu/h)	15.9 t/h (585 bu/h) to 18.1 t/h (665 bu/h)	11.6 t/h (425 bu/h) to 12.3 t/h (450 bu/h)	15.1 t/h (555 bu/h) to 19.9 t/h (730 bu/h)	14.1 t/h (515 bu/h) to 16.9 t/h (620 bu/h)
Barley	24.7 t/h (1135 bu/h) to 26.7 t/h (1225 bu/h)	17.0 t/h (780 bu/h) to 23.1 t/h (1060 bu/h)		20.2 t/h (925 bu/h) to 23.7 t/h (1090 bu/h)	
Oats	29.1 t/h (1885 bu/h) to 36.9 t/h (2390 bu/h)				

Figure 9. Discharge Length of 305 m (100 ft).

POWER REQUIREMENTS

Figure 10 shows that a maximum power take-off output of 60 kW (80 hp) was required when the Tractor-Vat was empty, conveying only air, with the air regulator valve held wide open by hand. This maximum amount of air flow was required under extreme conditions as may occur when the Tractor-Vac plugged. Under normal operating conditions the air regulator valve was controlled automatically. Average power requirements when conveying only air, with the air regulator valve in its normal position, was 47 kW (63 hp). As more grain was conveyed, less air was pumped, reducing the power requirement. The power required for conveying grain varied from an average of 41 kW (55 hp) in wheat and barley, to 47 kW (63 hp) in oats.

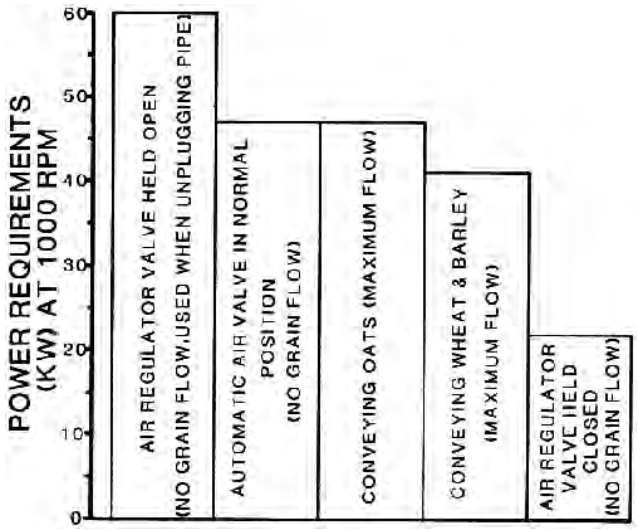


Figure 10. Average Power Requirements for the Tractor-Vac 9481.

Since maximum power consumption was when moving only air, high start-up torques could be decreased by holding the air regulator valve closed. This resulted in a decrease in power from 47 kW (63 hp) with the air regulator valve in its normal position to 22 kW (30 hp) with it held closed. It is recommended that to allow one man to start the Tractor-Vac at reduced torque, a manual lock be incorporated on the air regulator valve to hold it closed during start-up.

The minimum size of tractor that could be used on the Tractor-Vac 9481 was a 60 kW (80 hp) tractor with a 1000 rpm power take-off.

GRAIN DAMAGE

Figure 11 shows the increase in grain crackage each time a sample of dry wheat (10.4% moisture) was conveyed by the Tractor-Vac. In these tests the Tractor-Vac was equipped with the standard discharge assembly (Figure 2) as well as 4267 mm (14 ft) of flexible (rough) intake pipe. The wheat initially contained 1.8% cracks. Each pass through the Tractor-Vac caused an average 0.25% increase in crackage. This indicates that if the number of passes through the Tractor-Vac is kept to a minimum, grain damage should not be a problem. Test results[1] from grain augers in dry wheat have shown that each pass through an auger may cause from 0.1% to 0.9% crackage, depending on the type of auger.

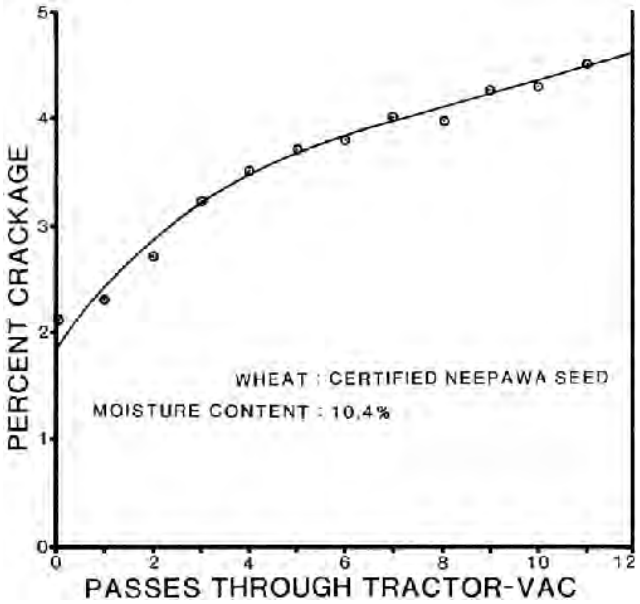


Figure 11. Grain Crackage Caused by the Tractor-Vac in Dry Wheat.

In addition to visible grain crackage, a small amount of fine grain dust (flour) was always noticed in grain (especially dry wheat), which had been conveyed by the Tractor-Vac. Flour dust was also always emitted by the discharge cyclone. After 10 passes of dry wheat through the Tractor-Vac, about 0.3% was turned to flour. This indicates that loss due to fines is about 0.03% for each pass through the Tractor-Vac, which is quite insignificant. Figure 12 shows the accumulation of wheat flour in a truck unloading chute and an unloading hopper.

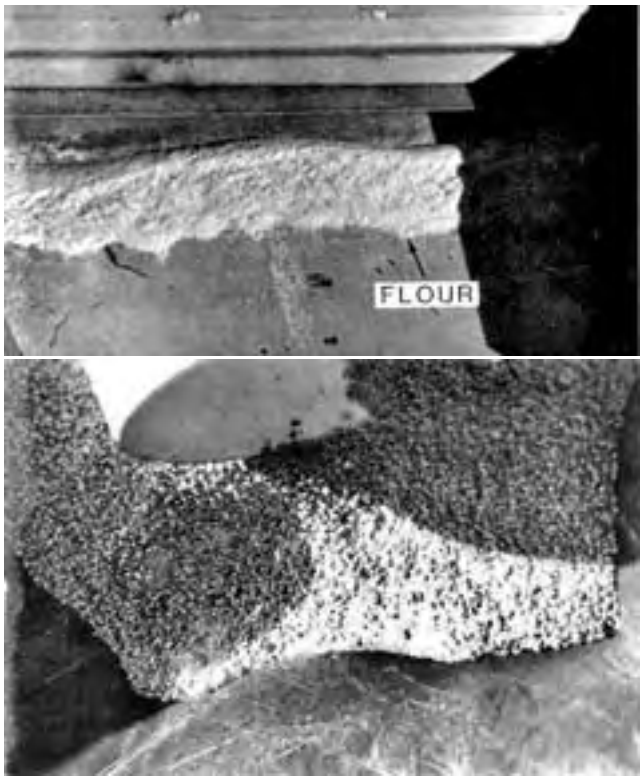


Figure 12. Wheat Flour Accumulation in Unloading Chutes when Emptying a Truck, which had been Loaded with the Tractor-Vac.

[1] *Data obtained from Agricultural Machinery Administration test report numbers 1760, 1860, 2262, 2362 and 2063.*

SAFETY

The Tractor-Vac 9481 was safe to operate and all moving parts were well shielded. The air intake nozzle was much safer to operate than a grain auger since there was no exposed flighting or rotating parts.

Working near the intake nozzle was clean since most dust was conveyed into the inlet. In this respect, the Tractor-Vac was cleaner than an auger when emptying bins, which could be of benefit to people with allergies. Working near the discharge outlet was dusty. Removing and attaching the discharge cyclone without proper equipment and assistance could be hazardous.

Provincial highway regulations require displaying a slow moving vehicle (SMV) sign when transporting machinery on public highways; the Tractor-Vac was not equipped with a SMV sign nor was there a bracket to attach a sign.

Since the centre of gravity of the Tractor-Vac is high and offset from the wheel centre line (Appendix I), care should be taken in towing the Tractor-Vac at high speeds on rough roads to prevent overturn. Removing the discharge cyclone lowers the centre of gravity and improves stability.

OPERATOR'S MANUAL

The automatic air regulator adjusting instructions were very useful in obtaining optimum regulator setting.

Instructions on nozzle use and adjustment indicating that the round nozzle should be immersed to at least half its length into the grain, gave low and unsatisfactory conveying rates. Optimum conveying rates occurred only with the nozzle inlet partially buried in the grain and with space for air entrance.

It is recommended that the operator's manual be revised to indicate proper use of the intake nozzles. The manual should also include assembly instructions for mobile discharge cart assembly and adjustment.

APPENDIX I
SPECIFICATIONS

Model:	Tractor-Vac (9481)	
Serial Number:	6125	
Dimensions:		
-- overall length	2499 mm(8.2 ft)	
-- overall width (transport)	2499 mm(8.2 ft)	
-- overall width (operating)	6279 mm (20.6 ft)	
-- wheel tread	1707 mm (5.6 ft)	
-- overall height complete with discharge cyclone	3901 mm (12.8 ft)	
Intake Discharge Pipe:	diameter 203 mm (8 in)	
	Length	**Weight**
Flexible Pipe:	3048 mm (10 ft)	15 kg (33 lb)
	4267 mm (14 ft)	18 kg (40 lb)
Rigid Pipe:	2438 mm (9 ft)	15 kg (33 lb)

	Standard Discharge	**Mobile Discharge Cart**
Discharge Height:	3200 mm (10.5 ft)	5486 mm (18.0 ft)
Discharge Reach:	1676 mm (5.5 ft)	5029 mm (16.5 ft)
Lubrication:		
-- packed wheel hubs	2	
-- pressure grease fittings	11	
Drives:		
-- power take-off	1000 rpm	
-- fan drive	V-belts	
-- air lock drive	V-belt & roller chain	
Discharge Cyclone:		
-- weight	34 kg (74 lb)	
Tires:	2, 6:70 x 15 × 4-ply	

Weight:	**Transport Position**	**Working Position**
-- right wheel	391 kg (860 lb)	200 kg (400 lb)
-- left wheel	563 kg (1240 lb)	636 kg (1400 lb)
-- hitch point	209 kg (460 lb)	327 kg (720 lb)
Total	1163 kg (2560 lb)	1163 kg (2560 lb)

Centre of Gravity:	**Transport Position**	**Working Position**
-- above ground	1029 mm (40.5 in)	1029 mm (40.5 in)
-- forward of trailer axle	307 mm (12.1 in)	483 mm (19.0 in)
-- in from left wheel	813 mm (32.0 in)	625 mm (24.6 in)

Mobile Discharge Cart Weight:	
-- left wheel	76 kg (167 lb)
-- right wheel	76 kg (167 lb)
-- at front pipe	28 kg (61 lb)
Total	180 kg (395 lb)
Optional Equipment:	mobile discharge cart support kit on wheels
	rigid straight pipe
	flexible pipe 3048 mm (10 ft)
	elbows 30°, 45°, 60°
	127 mm (5 in) clean up line
	102 mm (4 in) clean up line

APPENDIX II
MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

(a) excellent	(b) very good
(c) good	(d) fair
(e) poor	(f) unsatisfactory

APPENDIX III
METRIC CONVERSIONS

In keeping with the intent of the Canadian Metric Commission, this report has been prepared in SI units. For comparative purposes, the following conversions may be used.

1 millimetre (mm) = .0394 inch (in) = 0.00328 feet (ft)
1 tonne (t) = 1000 kilogram (kg) = 2204.6 pound (lb)
1 kilogram (kg) = 2.20 pound (lb)
1 tonne per hour (t/h) = 2204.6 pound per hour (lb/h)
= 36.74 bushel per hour (bu/h) for 60 lb/bu wheat
= 45.93 bushel per hour (bu/h) for 48 lb/bu barley
= 64.84 bushel per hour (bu/h) for 34 lb/bu oats
1 kilowatt (kW) = 1.34 horsepower (hp)
1 tonne per kilowatt-hour
(t/kW-h) = 27.42 bushel per horsepower-hour (bu/hp-h) for 60 lb/bu wheat.
= 34.28 bushel per horsepower-hour (bu/hp-h) for 48 lb/bu barley.
= 48.38 bushel per horsepower-hour (bu/hp-h) for 34 lb/bu oats.
1 kilometre per hour (km/h) = 0.621 miles per hour (mph)

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