

VIBRATED SIEVING SHARES FOR POTATO HARVESTING

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The design and performance of several vibrating share models are presented and the problems with each model are discussed. The shares were assembled on a prototype potato harvester for evaluation. Each model successfully enhanced soil sieving but created problems with soil flow. The last vibrating share model built was the most complex and was the final attempt to improve soil flow. The draft force and soil sieving capability of this model was compared to that of a plain share to evaluate the share performance. The vibrating share model performance was also compared to that of the oscillating share by evaluating the potato damage level of each.

INTRODUCTION

Concern with increasing potato harvester size, capital costs and operating costs has created an emphasis for studying tuber-soil separation efficiency. Tuber-soil separation improvements would allow the conveyor bed length to be reduced which would lead to smaller machines and related benefits such as reduced capital costs, less compaction, and lower power requirements. Ultimately a smaller machine with fewer and shorter drops, less travel and easier operator visibility will reduce mechanical damage. Better handling may allow more stones and clods to be taken to storage where a final separation could be done, further simplifying the harvester requirements.

McRae (1978) provided a summary of several workers' efforts on many potato harvester system components. The digger blade or share was the first component selected for development at the Fredericton Research Station. Many workers have studied share design for draft and damage reduction potential as well as increased sieving. A vibrating share developed by Johnson (1974) appeared to lower draft forces and tuber damage while improving material flow and sieving. McGechan (1977) provided information about vibrating horizontal digger rod displacements and peak acceleration on soil sieving effectiveness as well as resulting potato damage related to displacement

directions. Verma et al. (1977) reported reduction in potato damage using a vibrating share with simple arc oscillations closely approximating the horizontal forward oscillations used by others. Most workers' results were quite positive, and therefore the vibrating share was included as a component for a prototype harvester. The purpose of the vibrating share was to reduce machine draft and help reduce tuber injury by controlling the soil level on the harvester beds. An adjustable vibrating share, with variable sieving rates, was expected to continually maintain soil on the harvester beds under a variety of conditions. The soil cushioning the potato on the main digger bed minimizes tuber damage. Hyde et al. (1983) used an automatic chain load control to regulate the soil loading on conveyor beds.

MATERIALS AND METHODS

Design of Vibrating Blades

Over a period of 4 yr, five vibrating share models were designed and evaluated. Each successive model was a modification of the previous one in an attempt to reduce an identifiable problem. The performance of the final model was compared to that of a plain flat share by measuring the variables, draft and soil sieving. The physical design specifications are listed in Table I for all the vibrating shares.

Test Share

Initially, a single row test share was designed and built to demonstrate the lifting and soil-tuber separation process. The share had a flat blade with rods attached perpendicular to the trailing edge as shown in Fig. 1. The share oscillated in an arc motion about a pivot line inclined 25° forward from vertical centered over the row. The pivot point was centered on the base of a U-shaped frame suspended below a tool bar. The share was attached to the pivot point above the base. The oscillating motion gave the blade a horizontal velocity component and a small vertical component. The vibration amplitude was adjustable in three increments, and the frequency was variable up to 7.5 Hz. This share was evaluated late in the fall under adverse harvesting conditions (moisture content above 30% dry weight basis and temperature 0-5°C). The tests indicated that the vibrating share concept seemed promising. The soil-clod-potato distribution coming off the end of the vibrating blade rods met expectations. There was good soil movement perpendicular to the rods and only a small amount of soil was not separated from the potatoes. The rods on the side walls also removed soil. Tubers were damaged rolling off the rod ends; however, it appeared that adding the digger chain under the rod ends would probably prevent this problem. Under the moist conditions, it

TABLE I. PHYSICAL DESIGN SPECIFICATIONS FOR THE VIBRATING SHARES

Share type	Blade							Rod		
	Length (mm)	Thickness (mm)	Depth (mm)	Lift angle (°)	Force (N)	Torque (N/m)	Displacement (mm)	Frequency (Hz)	Length (mm)	Diameter (mm)
Test share	660	13	125	25° 20°	13340	1600	±8.5, 12.5, 25	0 7.5	300	12.7
Horizontally oscillating share	710	13	255	15°	6670	800	±0, 25	0 7.5	350	12.7
Horizontally reciprocating	1550	16	150	15°	6670	550	±0, 25	0 7.5	400	12.7
Horizontally-opposed reciprocating cantilever	810	25	150	15°	6670	550	±0, 25	0 7.5	350	12.7

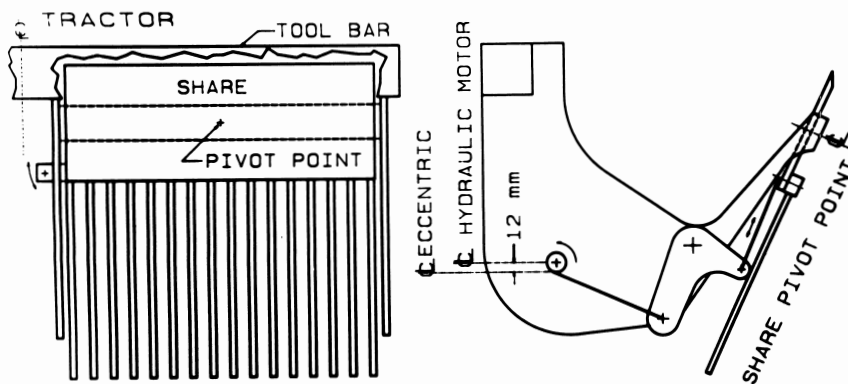


Figure 1. Single test share.

slots and bolt arrangements for adjusting amplitudes from ± 0 to 25 mm.

(f) To avoid a potentially high wear location the pivot point was moved to the tool bar. This arrangement also changed the side frames from passive to active surfaces vibrating with the share blade as a single unit. This was expected to reduce contact friction with the soil.

The shares incorporating these changes were called horizontally oscillating shares and were used on a two-row prototype harvester reported by Misener et al. (1984).

Horizontally Oscillating Shares

Horizontally oscillating shares (Fig. 2) were developed which were driven by a common eccentric with an arc movement similar to the test share except that the pivot center line was vertical. The shares rotated in opposite directions for balance. These shares were evaluated for damage as part of the total harvester evaluation reported by Misener et al. (1984). In early testing, spillage, including soil and tubers, occurred around the side edges resulting in vines wrapping. Small side plate extensions were added ahead of the original sides which reduced the problem sufficiently to allow harvester testing. As long as amplitude and frequency were maintained above ± 12.5 mm and 3.5 Hz, respectively, the share sieving effectiveness appeared constant. As reported in the test results, soil separation was completely satisfactory but a problem of excessive skinning occurred between the rod ends and digger bed where the relative movement pinched tubers. To avoid pinching, the rod movement in the same direction as the bed must have a lower velocity and the only practical method to achieve this was to use vibrating shares with horizontal amplitudes parallel to the digger bed rods. While this change was necessary for tuber quality, other improvements such as simpler drives and linkages and reduced soil-metal friction could be achieved. Soil-metal friction could be reduced by fabricating a single blade share that eliminates the two inner side walls.

Once the decision was made to use reciprocating motion parallel to the digger bed rods, a two-row, single blade share became practical. This new model was identified as a horizontally reciprocating two-row share and it retained some characteristics of the oscillating model while eliminating others.

(a) Pointed share blades to minimize soil intake were not practical for the two-row share.

(b) Work by McGechan (1977) indi-

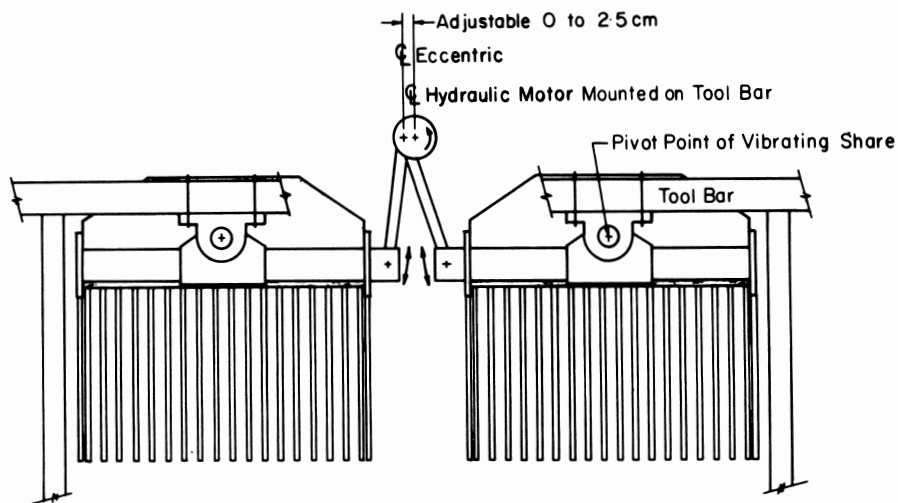


Figure 2. Oscillating share.

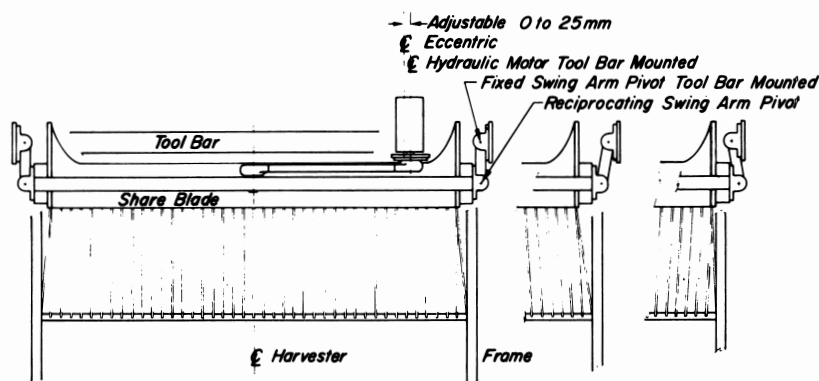


Figure 3. Reciprocating two-row share (pivoting rods).

seemed that large amplitudes separated soil more effectively than small amplitudes. There was some soil spillage and vines wrapping around the side edges of the share. These problems were believed to be caused by friction between the soil and the share as well as the soil physical conditions. It was felt that the flow of soil could be improved by amplitude and/or frequency changes. As a result of the observations on the test share the following changes were considered necessary to improve the performance.

(a) The blade was widened to reduce vine wrapping at the edges and to allow more room for relative soil-blade movement for reducing friction.

(b) A pointed blade was used to reduce the amount of material lifted.

(c) The blade angle was lowered to reduce friction forces and soil build-up while the rod length was increased to maintain the total lift.

(d) The number of side rods was increased to stop tuber losses.

(e) The drive eccentric was changed to

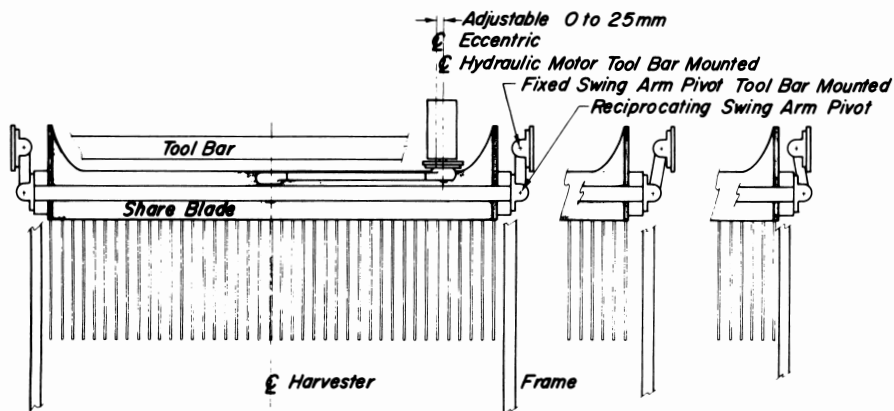


Figure 4. Reciprocating two-row share (fixed rods).

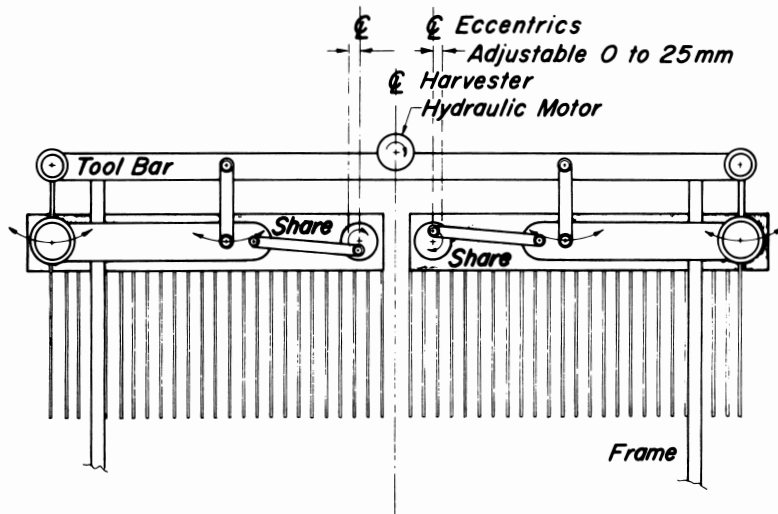


Figure 5. Horizontally opposed cantilever reciprocating shares.

cated that the vibration directional change had little effect on sieving efficiencies so the sieving area was maintained constant by keeping the same rod length.

(c) The rods were attached to the share with slots and pivots and were attached to the frame at the front of the main bed by pivots. This arrangement provides a smooth transition between share and bed movements.

Horizontally Reciprocating Two-row Share

The single blade share was designed (Fig. 3) and both side plates were connected forward on the harvester frame with two parallel swing arms 15 cm long. The drive was a hydraulic motor with an eccentric using slots and bolts for amplitude adjustments and a connecting rod to drive the crossmember. The side plates were joined together by the crossmember at the top and the share blade on the bottom. The crossmember and side plates were part of the linkage that drove the share blade. The swing arms transmitted the blade draft force and bending moment to the frame and the eccentric linkage

transmitted the acceleration force. The sieving rods were inserted into hydraulic hose sleeves that were connected perpendicular to the share trailing edge. The flexible sleeves allowed the rods to slide and to rotate as the vibrating share moved back and forth horizontally. The sieving rods were also connected to the frame at the main bed and were only free to rotate at this point. The sieving rods reciprocated with the share, giving the rods a maximum horizontal displacement at the share and a minimum of 0 at the bed. This reduced the average acceleration to one-half the acceleration that existed when the rods were rigidly attached to the share. The reduced acceleration caused a loss of sieving capacity that was expected to be compensated for by the opening and closing of the gaps between the sieving rods.

This share was taken to the field for testing, and observations indicated that the material did not flow across the sieving rod surfaces. The loss in average acceleration was not compensated for by the relative sieving rod movements. Material spilled around the side edges and

vines wrapped before the soil bulk would slide over the sieving rods.

The full acceleration of the sieving rods was re-established by welding them fixed to the trailing edge of the share and removing the pivot points at the main bed. The sieving rods now were a rigid extension of the share blade (Fig. 4).

After the modification, material flowed across the vibrating share with a gradually declining flow rate until plugging occurred. A decline in share acceleration was experienced as material flowed onto the system and the accumulated mass on the vibrating share increasing the displacement force. The light-weight harvester did not have enough mass to effectively absorb this force without a measurable deflection. Acceleration of the share declined as the soil mass accumulated until the harvester vibrated more than the share and the flow stopped. The dry soil conditions of 20–22% moisture (db) aggravated the problem because it was crumbly and unable to hold together as a block for feeding onto the harvester. Vines spilling and wrapping around the sides appeared to be the final factor that stopped the flow of material. Attempts to counterbalance this share were not successful. Acceleration still appeared to have potential for sieving and enhancing material flow if it could be controlled. This was not achievable with this model and whatever system was used it would have to be nearly self-balancing. The original two-row oscillating shares were essentially self-balancing which indicated that the next logical step was to design a two-share unit moving in the same line but in opposing direction. Assuming uniform rows and uniform treatment, the two shares should balance.

Horizontally Opposed Reciprocating Cantilever Shares

Reciprocating shares (Fig. 5) were designed, specified and tendered for construction. The cost to manufacture the unit was \$3100.00.

Each share was composed of a flat blade with fixed sieving rods and a vertical hollow tube connector for transmitting torque to a top arm parallel to the blade. The pivot arms on the side were made with two parallel steel tubes connected together with a vertical steel plate. The tubes were machined into bushings that carried draft forces and couples as well as providing pivots through which the shares could reciprocate. The link on the top arm connected the arm to the harvester tool bar and formed a parallel linkage with the pivot arms to keep the share parallel to the

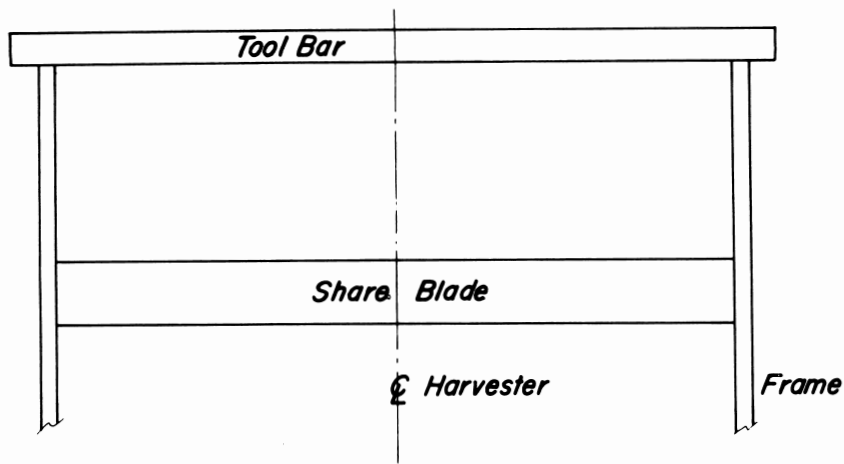


Figure 6. Plain share.

tool bar. Two adjustable eccentrics were connected to each other and a hydraulic motor and were in turn connected to the top arms. This combination provided the reciprocating share motion and the linkage for one share to counterbalance the other. In operation, no significant vibration was transmitted to the harvester from the shares. During testing, the share acceleration could not be adjusted to obtain smooth soil flow. The soil flow was improved compared to the single share flow because the shares did not plug as readily. The flow was erratic, producing material surges that created problems throughout the harvester. It was possible to overcome the erratic flow in order to evaluate the vibrating share for sieving and potato damage levels by removing the vines before harvesting.

Test Procedures

Potato injury caused by the oscillating and the reciprocating shares were determined. It was not practical to install both units in one harvest season so the comparison was between 2 yr. The ambient temperatures were similar but soil moistures ranged from 22–24% db for the reciprocating unit to 26–28% db for the oscillating shares. The tests were conducted at three harvester forward speeds, 1.6, 2.4 and 3.2 km/h. Damage samples were taken from the sieving rod ends to a point 15 cm up the digger bed. The samples were bagged, recorded and stored at room temperature for 3 wk. The tubers were then washed and assessed for injury by peeling with an ordinary potato peeler. The damage was classified as follows:

- (a) Undamaged.
- (b) Scuffed or skinned—damage that does not break the tuber flesh.
- (c) Peeler—damage removable with a 3-mm-thick slice.
- (d) Severe—damage not removable

with a 3-mm-thick slice.

For testing, the oscillating shares were operated at 4.5 Hz with an angular amplitude of $\pm 1.9^\circ$, resulting in a maximum displacement range of ± 16 mm. The reciprocating share was operated at 7.5 Hz for the entire test with a horizontal amplitude over the entire share of ± 9 mm. In both cases the shares were operated near the optimum of their soil separating ranges.

The reciprocating share represented the culmination of several years of evolution towards enhanced soil sieving and so its sieving capability was compared to a plain share (Fig. 6) which represented the digging system on a standard commercial harvester.

The draft requirements of the reciprocating and plain share types were determined by towing the harvester and tractor with a second tractor and measuring the draft required by the harvester-tractor combination. The harvester-tractor combination draft was measured for 25 m at a forward speed of 1.6 km/h. This was done for the tractor-harvester without digging to get the rolling resistance. It was repeated using the vibrating share on and off and then finally using the plain share. The difference between the forces represented the share draft in a very approximate manner.

To compare the share effect on the main bed sieving, the amount of material in a row was determined. One-meter row sections were analyzed by weight of soil, clods and tubers. After operating the harvester, the soil depth on the main bed at the head roll was determined. The maximum sieving rates were calculated from the soil depth, row volume and harvester speed.

RESULTS AND DISCUSSION

Every change in vibrating share design

throughout the project was an attempt to reduce soil-metal surface friction and the resulting vine wrapping. At no time was this accomplished as the soil structure broke down faster than the soil-metal friction could be reduced which limited the soil flow across the share.

Visual observations conclude that flow across the share was better with the oscillating units than with the reciprocating shares. The vibration of the oscillating share increased in the soil flow direction breaking down the soil structure as the flow progressed. This allowed the soil structure at the share entry to remain intact to provide the force necessary to push the unsieved soil across the share. With the reciprocating share, soil structure breakup began at the lead edge and there was less soil structural strength available for pushing the unsieved soil.

Tuber damage was reduced as shown in Table II by using the reciprocating share instead of the oscillating unit. This improvement is attributed to reduced pinching between the rods and main bed.

The soil sieved through the share rods was less than expected as only 60% of the available volume under the rods was filled with soil. This is primarily because the tubers, stones and clods concentrated on the rod surface as the finer material filtered through the opening and effectively reduced the open sieving area from 70% to about 30% of the surface.

The breakup in soil structure is considered the main factor causing the wrapping problem with vines. There are two stages; the first is the soil block buildup and the second is the loosening of the vines from the soil and their subsequent flow forward off the soil block around the lead edges.

The enhanced sieving by the combination of vibrating shares and main bed was impressive, as displayed in Table III, but it must be recognized that soil conditions were ideal for sieving. The sieving capacity of 215 and 81 t/(m²/h) are relative and effects of higher soil moisture content must be considered. In one case, with preliminary work in a heavy soil with high clod content not normally planted to potatoes, the effective sieving rate was reduced from 215 to 80 t/(m²/h) under dry soil conditions.

The vibrating share cost is equivalent to 6 m² of webbed belt. When interface drops, direction changes, large relative belt speeds and belt shaking are considered, the vibrating share is estimated to replace 8–10 m² of webbing-based sieving capacity. This would make the shares cost effective.

There is an inconsistency with the results between draft for the plain share and

TABLE II. COMPARISONS OF TUBER INJURY CAUSED BY THE TWO TYPES OF VIBRATING SHARES

Share type	Damaged tubers (% wt)†			
	Undamaged	Scuffed	Peeler	Severe
Oscillating	48.6	9.0	39.0	3.4
Reciprocating	59.1	23.1	16.0	1.8

†Means of nine samples.

TABLE III. DRAFT AND SIEVING RATES FOR THE VIBRATING (RECIPROCATING) SHARE AND PLAIN SHARE

	Maximum sieving rate (t/m ² /h)	Share draft at 1.6 km/h (N)
Vibrating share	215	8435-9800
Vibrating share off		11570-12000
Plain share	81	4900-5400

the vibrating share as shown in Table III because Johnson (1974) had generally more draft on the plain share. The draft reduction between the vibrating share on and off was expected but the lower draft for the plain share was unexpected. The plain share had a soil travel distance of only 150 mm compared to 500 mm for the vibrating share and the built up soil block caused by the large travel distance must account for the increased draft. Forward or vertical share vibration motions were not incorporated because of possible interfacing problems and/or bruising, but there is little doubt that their quick return component would enhance soil flow and possibly reduce draft.

The single blade for two rows was found difficult to balance and much of the share vibration was transmitted to the

harvester particularly as the soil mass accumulated on the share. Using two counter-vibrating shares worked well as the load on each share approximately counterbalanced and the harvester mass absorbed the differential forces with minimal displacement.

CONCLUSIONS

Soil lifting problems limit future applications of horizontally vibrated sieving shares for potato harvesting. Their general performance can be summarized as follows:

1. The vibrating share enhanced soil structural breakdown and subsequently improved soil sieving rates by as much as 265%.
2. The advantage of improved soil sieving rates by vibrating shares was offset by poor soil flow because the vibration could not sufficiently reduce the soil-metal friction.
3. The oscillating blades sieved better than the reciprocating units and had better flow characteristics.
4. The oscillating blades caused more tuber damage than the reciprocating units, and this damage occurred where the rods met the digger bed.

5. Single unopposed vibrating shares should be avoided particularly if the maximum forces apply perpendicular to the travel direction.

6. The plain share had less draft than the reciprocating shares because of less surface area and a smaller accumulated soil block at the harvester entrance.

7. All shares lifted better under moist conditions but sieving rates were higher under dry conditions.

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