Design of an Antiseptic Potato Seed Cutter Using a Water Jet Cutting System

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Introduction:

The purpose of this research project is to investigate the possibilities of developing an antiseptic potato seed cutter. There is a growing concern in today's potato crop production involving the spread of diseases which can start with the seed cutting process. To obtain maximum production out of the seed, the potato tubers are cut into appropriate sizes for planting. Potato seed cutters are typically designed around the use of metal knives. Metal knives have been found, not to be completely antiseptic, and can cause diseases to spread during the cutting process. To control the spread of these diseases and keep the knives antiseptic, the knives are often sprayed with disinfectants. These disinfectants are costly because they can cause extensive corrosion on the machinery and are not completely effective. In order to reduce the spread of diseases from the use of metal knives, another means of cutting seed potatoes should be developed. This new means will not be able to eliminate diseases in potato crops, but it should reduce the spreading of them.

It has been found from research done by Becker and Gray in 1992 that potato tubers can be cut with water at pressures ranging from 15,000 - 30,000 psi. Water jet cutting systems are used in many industry applications. They are applied in mining and construction operations and are also used for cutting many types of materials. Unlike the cutting edges of knives, water does not become dull or contaminated. The use of water jets can possibly be used to eliminate both the metal knives and disinfectants found in potato seed cutters.

Objectives:

The purpose of this research project is to develop an antiseptic potato seed cutter that will reduce the spread of diseases. It is important to determine whether or not water can be used to cut a potato tuber instead of using a metal knife. It will also be necessary to determine the effects, if any, that cutting with a high pressure water jet will have on the seed piece. The main objective for this project is to design and analyze a water jet cutting system for cutting seed potatoes.

Background:

As potato growers, we are interested in providing the consumer with a product of high quality. We are also interested in having a high yielding crop, so that a profit can be made from our investments. In order to do this we must be able to control the amount of diseases that our crops contain. Diseases found in potatoes are caused by viruses, bacteria, and fungus. Diseases have been threatening potato farmers for hundreds of years and they affect both the quality and quantity of the crop. Such diseases as late blight have been know to destroy entire crops within days. Most diseases found in potatoes plants are viral, therefore they can be passed on from plant to plant through insect or human contact. They can also be passed on from generation to generation through the seed.

One way that diseases spread has been increased is through the seed cutting process. The seed cutting process increases the plant number by cutting the tuber into seed pieces about two ounces in size and planting each piece. When a contaminated seed piece is split and both pieces are planted, this doubles the amount of disease present in a crop.

Metal knives are the basis upon which potato seed cutters are typically designed. Metal knives are placed in the machinery and are used to cut the potatoes that are used for seed. As the potatoes go through the machinery, they are aligned and cut into pieces of the appropriate size for planting. It is believed that these metal knives are not antiseptic and can cause the spread of diseases. When a contaminated seed piece is cut by a knife, that knife then becomes contaminated and could possibly pass on the disease to the other seed pieces cut by that same knife. In order to control the spread of diseases and keep the knives antiseptic, the knives are often sprayed with several types of disinfectants. A commonly used disinfectant is sodium hypochlorite. Disinfectants, however, are not completely effective and are often costly. The cost may not be seen in the expense to disinfect the machinery, but rather in the quality of the seed piece. When the disinfectants are sprayed on to the metal knives it causes them to corrode. This brings about the need for a cleaner and more effective way of cutting seed pieces.

Some testing has been conducted around designing seed cutters using knives at increased temperatures. The increased temperatures are used to keep the knives antiseptic, but cutting with high temperature cauterizes the seed piece and does not allow oxygen to enter the tuber. Oxygen entering the seed piece at the time of planting is important for the proper healing of the seed piece. Lasers could possibly be used to cut the seed piece, but it is believed that the heat produced from the laser would also cauterize the cut surface.

A water jet cutting system could be used to cut potato seed pieces. Water jet cutting systems are used today in many areas of industry. In the construction industry, water jets are being used for cutting concrete, grooving pavement, and for high energy cleaning. They have been used for cutting materials ranging from ceramics to plastics including circuit boards, glass, foam, light metals, and wood products (Becker and Gray, 1992). These types of systems have also been applied to several food industry applications as well. Unlike the cutting edge of blades or saws, a water jet cutting system does not become dull or contaminated (Becker and Gray, 1992). It has also been found that no heating occurs at the cut face when cutting with water. Therefore, water jet cutting systems can replace both metal knives and disinfectants in a potato seed cutter.

In 1992 Becker and Gray evaluated a water jet cutting system for slicing potatoes. In their evaluation water pressures ranging from 10,000 to 55,000 psi were tested. Replaceable sapphire nozzles ranging from 0.003 to 0.002 inches in diameter were also researched. Becker and Gray also measured the depth of subsurface cellular damage that occurred in the potato after cutting them with a water jet. The stand off distance that they used between the nozzle to the cutting face was 1.4 inches. They determined that it is possible to cut raw potatoes with this range of pressures. Increasing the cutting speed decreased the subsurface cellular damage. The best cuts were obtained with the smallest orifice nozzle, regardless of pressure and cutting speed (Becker and Gray, 1992).

Using water at pressures of this magnitude can be dangerous to the operator and difficult to obtain. It is important to take the proper precautions when working with high pressures. The water jet should be enclosed from any type of human contact. Fittings and pipes built for these type of pressures should also be used to insure the safety of the operator. Highly sophisticated pumps are required to obtain pressures of these magnitudes. Harben Inc. produces a high pressure radial diaphragm pump, which ranges in pressures up to 10,000 psi. The cost for one of these pumps is estimated to be $20,000. Since these pumps are fairly expensive, it may not be cost effective to use water jets in potato seed cutters.

Rather than using a pump to produce high pressures with water, a hydraulic ram can be used for this research project to determine the possible capabilities of a water jet for cutting seed pieces. A hydraulic ram consists of two hydraulic cylinders in a series. One cylinder contains hydraulic oil. Pressure from this oil is produced by a hydraulic pump and an electric motor. The shaft from the first hydraulic cylinder is then used to force water in the second cylinder through a small orifice. The sizes of the cylinders and the orifice diameter of the nozzles determines the pressures that can be developed.

It is not known if pressures of this magnitude are feasible in a potato seed cutter. It will be important to determine whether potatoes can be cut at pressures lower than 10,000 psi and still heal properly for plant growth. Several factors should be considered when designing a prototype seed cutter using high pressured water. First, the pressures and nozzles required to produce a jet that will cut a seed piece will need to be analyzed. Also the thickness, length, and strength of the potato will affect the speed at which the seed piece can be cut. The safety of the operator when using this type of equipment should also be considered. If a water jet cutting system at lower pressures is capable of cutting potatoes and is more cost efficient than the traditional cutters, it could be a great asset to potato producers in controlling the amount of diseases spread.

Procedure:

The best approach to obtain a high pressure water jet was researched and determined. The cost to build a hydraulic ram versus the cost to purchase a high pressure pump were compared. It was determined that the hydraulic ram was the best alternative to use with the budget provided for this project. A hydraulic ram consisting of a hydraulic oil cylinder reduced to a smaller cylinder was designed after several aspects of the hydraulic ram were studied. The diameter and length of the two cylinders were established through calculations. Once the hydraulic ram was designed, the construction of it began. Several of the pieces needed to be fabricated on a metal lathe. After the components of the hydraulic ram were completed, they were fitted together. A stand which held the hydraulic ram vertically was designed and constructed. It was designed to allow the height of the ram to be adjusted to allow for the proper spacing between the nozzle and the belt so the potatoes could move freely through the water jet.

Two different nozzles were placed in the hydraulic ram and tested to determine the performance of each. The first nozzle that was tested had an orifice with a diameter of 0.014 inches. It was determined that this nozzle could not produce enough pressure when used with this type of setup. However, another nozzle was tested that had an orifice diameter of 0.010 inches and it was concluded that it was capable of creating enough pressure to run the test for this project. From this point, a conveyor table was designed and built to carry the potatoes through the water jet at different speeds and provide safety for the operator.

After the prototype water jet cutting system was completed, several testes were conducted using the nozzle containing a 0.010 inch orifice diameter. Using this nozzle, the water jet cutting system had a range of 4,000 to 11,000 psi, therefore pressures of 5,000, 7,000, 9,000, and 11,000 psi were analyzed. At each pressure tested, three different belt speeds were also looked at. Speeds of 0.09, 0.15, and 0.30 ft/sec were analyzed. The speed of the belts was adjusted by using the control flow valve connected to the orbit motor. The speed of the belt was determined by timing how long it took for the belts to travel a pre measured distance. Flow into the orbit motor was adjusted until the desired belt speed was obtained.

Four potatoes and a square metal shaft were placed on the conveyor table at one time while the belt was in motion. After the potatoes were placed on the table, the directional control valve on the cylinder was pulled down to create the water jet. As soon as the potatoes were cut the cylinder was stopped and the valve on the hydraulic ram was completely open. The cylinder was then forced up using the directional control valve to allow the lower cylinder to refill with water. Once the cylinder was refilled, the valve was closed again and the cutting process could begin once more. Three runs were conducted for each pressure and belt speeds that were analyzed. During each run, the oil pressure, oil flow rate, and the water pressure were recorded from the gauges placed within the system. For each test sample, which consisted of one pressure and one belt speed, twelve tubers of the Centennial Russet Burbank variety were cut. Once the twelve tubers were cut, they were placed in a sack which would allow air movement through the seed pieces. Twelve tubers were also cut by hand with a knife to be used as the control.

The sacks containing the cut samples were then placed in a suberization room, which was held at a constant temperature of 55° F and a relative humidity of 80%. These seed pieces were left in the room for ten days. They were then removed from the suberization room and placed in a cooler. The cooler temperature was held constant at 39° F and 40% humidity. After two weeks each tuber was observed and rated on a scale ranging from one to five. Five meaning no decay was present on the cut surface and that the seed piece had healed properly for growth. The ratings for this analysis were recorded and were used to calculate the percent of the samples that had healed properly. The above procedure was conducted rather than planting the cut tubers, due to the quality of the tubers at the time they were cut.

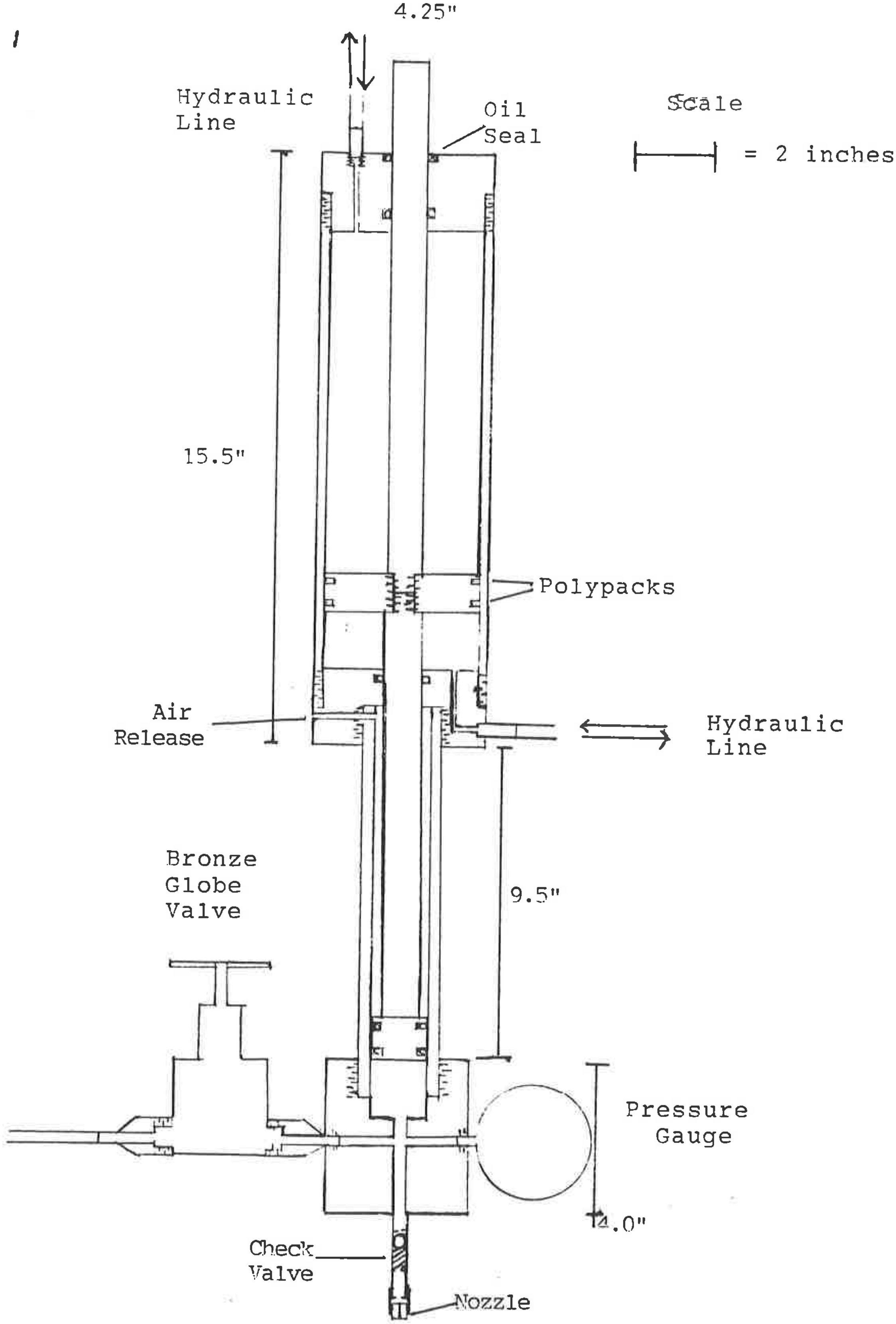
Results:

To begin this design project a way to create high water pressures ranging from 0 to 10,000 psi was researched. It was found through research that several high pressure pumps are available on the market. These pumps are capable of creating pressures up to 30,000 psi. Harben Inc., a manufacture of radial diaphragm pumps, was contacted about the cost to purchase a pump. The cost to purchase a pump from them that would create 10,000 psi was quoted to be around $18,000. A 89 Hp motor would also be required to drive the pump. Due to the budget provided, it was determined that a high pressure pump could not be purchased for this research project. Therefore, another alternative to create high pressure with water had to be established.

After several considerations, it was determined that a hydraulic ram could create enough pressure to meet the objectives for this projects. With a hydraulic ram, several samples could be cut with high pressure water to determine the range of pressure that could be used to cut potatoes and also the effects of cutting with water can have could also be investigated. However, the hydraulic ram would not be able to provide a seed cutter which would be capable of cutting many samples quickly. Rather than designing a hydraulic ram which consisted of two water cylinders it was decided to design a ram with one water cylinder to reduce expenses.

A scaled drawing of the hydraulic ram that was designed and constructed for this project can be seen in Figure 1. The hydraulic ram consists of a 4 inch diameter hydraulic oil cylinder which is 15.5 inches long. The shaft from this cylinder is then extended and placed into a cylinder having an inside diameter of 1.22 inches. Hydraulic lines are placed on the larger cylinder to force oil into the cylinder and control the force and speed of the shaft. Water enters the smaller cylinder through a bronze globe valve. A plastic hose is connected to the bronze globe valve and the other end of it is placed in a five gallon bucket where clean water is stored. Water enters the smaller cylinder due to the vacuum created within the cylinder as the shaft moves upward. Once the shaft hits the top of the cylinder the bronze valve has to be shut to prevent the water from leaking back through the valve. To create the high pressure water jet, the shaft is forced down and the water in the smaller cylinder is forced through the stainless steel check valve and a sapphire nozzle with a small orifice. A pressure gauge is placed at the end of the smaller cylinder to measure the pressures that are created with the ram.

Figure 1


4.25"
Hydraulic Line
Oil Seal
Scale
= 2 inches
15.5"
Polypacks
Air Release
Hydraulic Line
Bronze Globe Valve
9.5"
Line To Water Supply
Pressure Gauge
4.0"
Check Valve
Nozzle

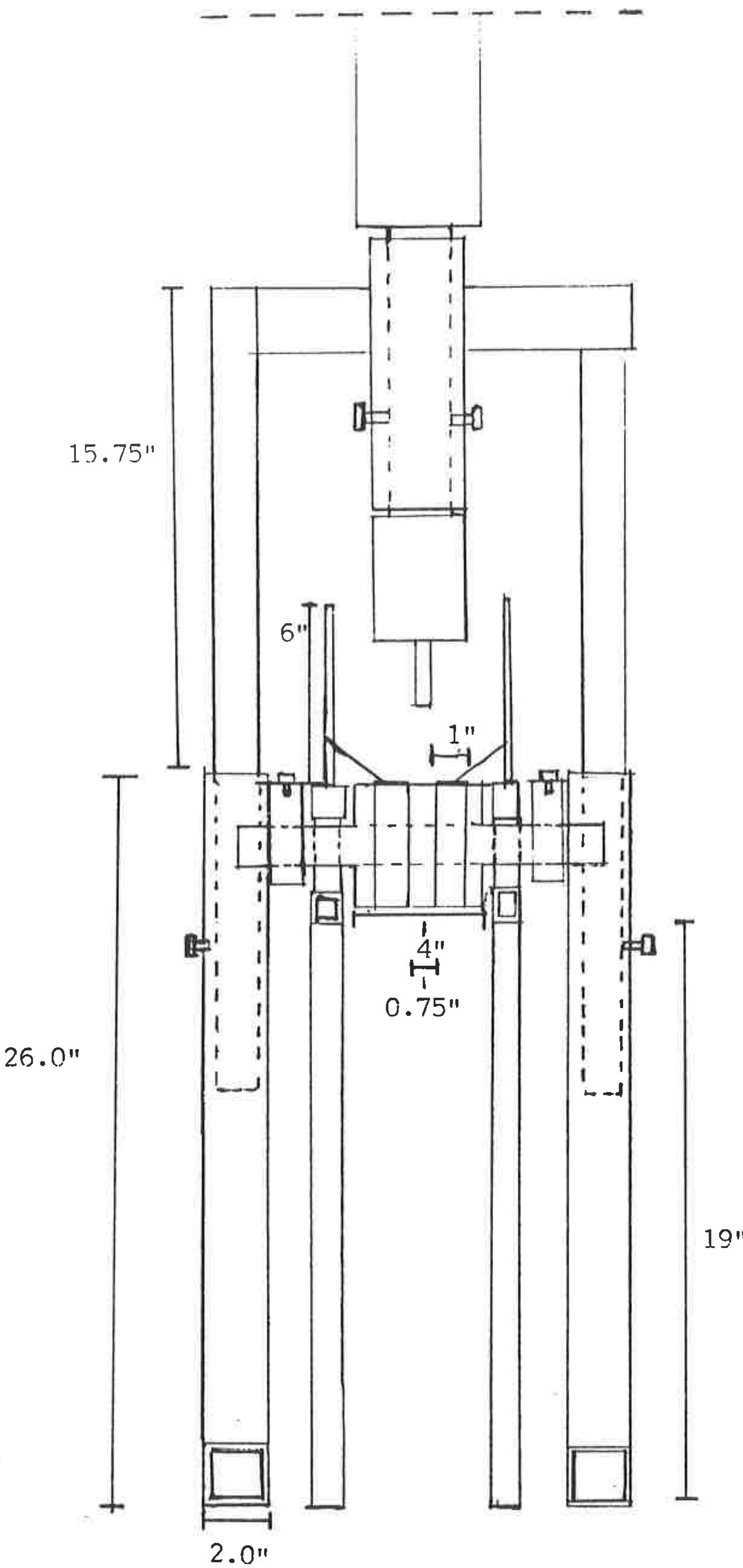
Once the hydraulic ram was designed and constructed, it was placed into a hydraulic circuit system. A Viking hydraulic gear pump was used and driven by a 3 Hp electric motor to operate the hydraulic ram. Along with the pump, a flow control valve was placed into the circuit to control the flow of the oil into the cylinder. By increasing or decreasing the flow of the oil into the cylinder the pressures created by the hydraulic ram could also be increased or decreased. A pressure gauge and a flow meter were also placed into the hydraulic lines. A directional control valve operated with a lever was used to control the hydraulic ram.

After the hydraulic circuit system was completed a stand was needed to hold the hydraulic ram vertically. This stand was designed so that the height of the hydraulic ram could be adjusted easily. Height adjustments are needed to provide the proper distances between the nozzle and the potatoes.

The next step in the project was to design and construct a conveyor table. The purpose of the conveyor table is to provide a means of moving the potato through the water jet and keeping it centered so that the potato could be approximately cut in half. A scaled drawing of the hydraulic stand and the conveyor table can be seen in Figure 2. The conveyor table has a width of 4 inches and is 3 feet long. Side plates 6 inches tall are placed on the side of the table to provide a shield for any human contact with the powerful water jet. Two automotive fan belts each 1 inch wide are used to develop the belt on the conveyor. These belts are placed 0.75 inches apart from each other to provide a gap for the water jet to go through. Slides were placed under the belts and angled toward the middle so that the potatoes would stay centered when placed on the belts. A hydraulic orbit motor was used to drive the belts. This type of motor was used so that the speed of the belts could be varied easily.

After the prototype potato seed cutter was constructed the first product that was analyzed was the sapphire nozzles. These nozzles were custom made by Stone Age Water Jet Engineering located in Durango, Colorado for a price of $23 dollars a piece. Two nozzles were purchased for this project. Each nozzle was made from a quarter inch pipe plug with a small sapphire insert placed within them. The small sapphire insert had the small orifices drilled into them. Sapphire is used in these nozzles to reduce the wear that occurs at high pressures. These nozzles consisted of an orifice diameter of 0.010 and 0.014 inches.

Figure 2



The 0.014 inch diameter nozzle was inserted into the hydraulic ram first and analyzed. The maximum pressure that was obtained from this nozzle was 4,000 psi. A potato was placed on the conveyor belt and sent through the water jet at this pressure. The water jet penetrated the potato but did not cut it completely through. The 0.010 inch nozzle was then inserted and tested. It was found that this nozzle could produce a maximum pressure of 11,000 psi. It was decided that the 0.010 inch nozzle would be used for the rest of the testing because it produced the pressures which meet the objectives for this project.

Before any data was collected, several samples were cut with the water jet to determine the minimum pressures that could be used and still cut the potato tuber completely through. From this analysis it was determined that the minimum pressure that could be used to cut the tuber was 5,000 psi. Once this pressure was found, the pressures that were to be tested on this project were established.

Four different pressures were analyzed using the prototype potato seed cutter. For each of these pressures tested, a total of three different belt speeds were also analyzed. A total of thirty-six runs were conducted for this analysis. For each run, the oil pressure, oil flow rate, water pressure, and the belt speed were measured and recorded. A tabular list of all the data collected for each run was compiled and placed in the Appendix.

Not only did the data collected provide useful information about this prototype potato seed cutter, but also the observations made during the testing were valuable to this project. Several problems occurred as the potatoes were sent through the water jet. If a single tuber was placed on the conveyor belt without anything else, the tuber would begin to spin immediately after it hit the water jet. Once the tuber would begin to spin it would slide on the belt and therefore would not travel through the water jet. In order to solve this problem it was decided that several potatoes had to be placed on the belt at one time and a metal shaft needed to be placed behind them so they could be pushed through the water jet. Since several potatoes and the metal shaft had to be placed on the belt at the same time, this limited the speed of the belt that could be analyzed

Another observation that was made was that the water jet began to spread out and dissipate at approximately 2 inches away from the nozzle. In order to use the water jet's cutting potential the potatoes had to be placed as close to the nozzle as possible. This was done by adjusting the stand so that approximately a 2.5 inch gap was provided between the nozzle and the conveyor belts.

The water that remained after the potatoes were cut was collected in a five gallon bucket, which was placed under the conveyor table. The water that was collected was very black and had a large amount of sediment in it. It would be very difficult to recycle this water in a hydraulic ram or high pressure pump. If it were to be reused it would have to be filtered and then the water wold have to be distilled to remove any contaminates. According to calculations using the 0.010 inch nozzle at 11,000 psi the water flow rate would be 0.22 GPM. If this prototype was operated under these conditions for twelve hours, 158 gallons of water would be required.

As was stated in the procedure, three different belt speeds were analyzed for each of the four pressures tested and a run was conducted three times for each belt speed to cut enough samples. Centennial Russet Burbank variety potatoes were used to conduct the testing. Centennials contain very high specific densities when compared to other potato varieties. By using this variety, the limits for this prototype could be better established. The potatoes used in the testing were harvested in September of 1996 and were kept in storage until the time of testing which was on July 3, 1997. Since the potatoes were in storage for so long they began to sprout and shrink slightly. The sprouts were removed from these potatoes several days before the testing was done, so that the sprouts would not hamper them as they traveled on the conveyor table. The surface of the potatoes, after they were cut, was observed and compared for each pressure and belt speed. Photographs of the potatoes for each pressure and the middle belt speed tested were taken after they were cut. These pictures can be seen in Figures 3, 4, 5, and 6.

When comparing the cut surfaces of the tubers for each pressure there is little difference seen. The cut surfaces were rougher and jagged at the lower pressure than they were at the higher pressures. However, it appeared that the cut surfaces were not too rough at the lower pressures. It also appeared that cutting the tubers at these pressures would allow the tubers to be planted and grow without any foreseen problems. There was also no significant difference seen

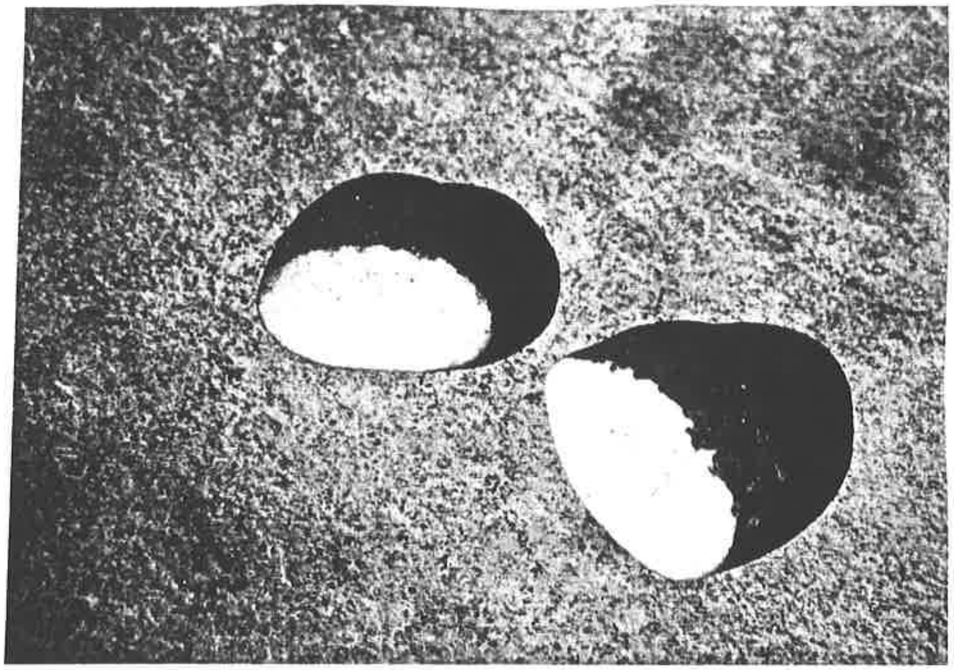


Figure 3 - Potato cut at 5,000 psi and 0.15 ft/sec

Figure 4 - Potato cut at 7,000 psi and 0.15 ft/sec

Figure 5 - Potato cut at 9,000 psi and 0.15 ft /sec

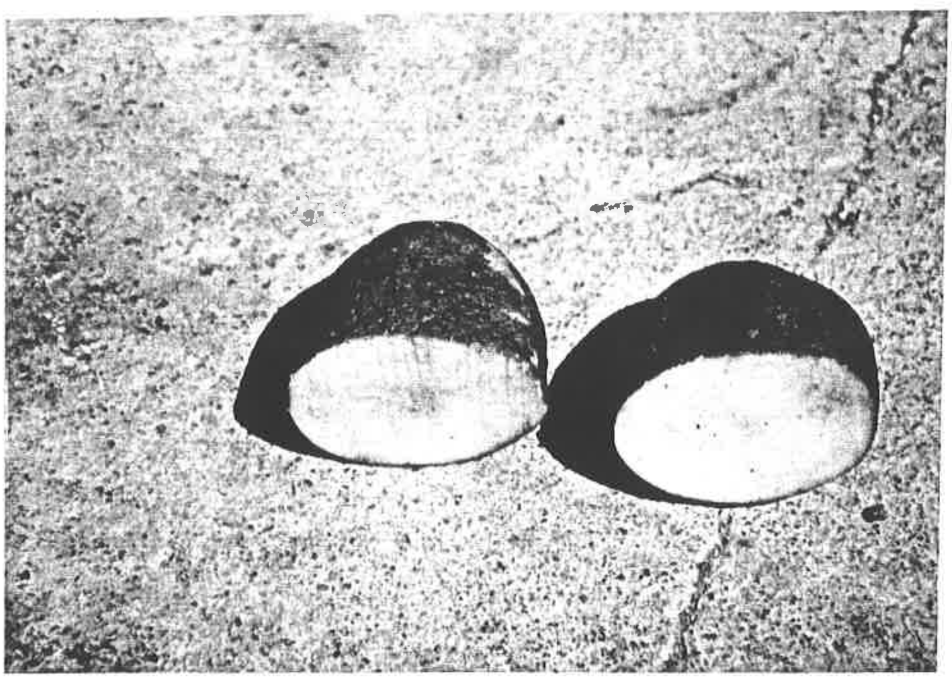


Figure 6 - Potato cut at 11,000 psi and 0.15 ft/sec

in the cut surface at the different belt speeds. The faster belt speeds produced a smoother cut surface. It appears that the faster the potatoes can be pushed through the water jets, less damage would occur.

After twelve tubers were cut with the prototype, they were placed in a ten pound mesh sack. In order to have a control for the storage and have something to compare to the cut samples, twelve potatoes were cut by hand with a metal knife and placed into a sack. Once all of the samples were cut, the sacks were taken and weighed on a scale. The weights of each sack were recorded and can be seen in the Appendix.

After all the weights were measured, the sacks were placed on the floor of a suberization room. The purpose of the suberization room is to provide a controlled environment for the cut potatoes to heal in. This room was held constant at 50° F, and a relative humidity of 80%. The temperature and the relative humidity were monitored daily. There were no drastic changes seen in the temperature until day ten in the storage. The temperature of the room got above 55° F, due to the warmer temperatures present outside that day. To prevent the cut samples from rotting and shrinking, they were placed into a walk in cooler, which was held at a temperature of 39° F and 40% relative humidity.

The cut samples were looked at and analyzed after three, seven, and fourteen days in storage. Photographs of a potato cut from each pressure at the middle belt speed and the control were taken together on each of these days. These pictures can be seen in Figures 7, 8, and 9.

When the tubers were looked at after being in the storage for three days it appeared that they were healing properly. A tough skin had formed on the cut surface, and little discoloration had developed, which can be seen in Figure 7. The tough skin that was present was a good sign that the cut surface was healing correctly. There was no significant difference seen in the different cut samples. The potatoes cut at the lower pressures were healing at the same rate as those cut with the higher pressures. There was also difference seen in the cut samples which were cut with different belt speeds. When compared to the control, it appeared that the cut samples were healing as fast as they were.

The cut samples were again looked at after being in the storage for seven days. As can be seen in Figure 8, it appeared that the samples were beginning to turn black on the cut surfaces

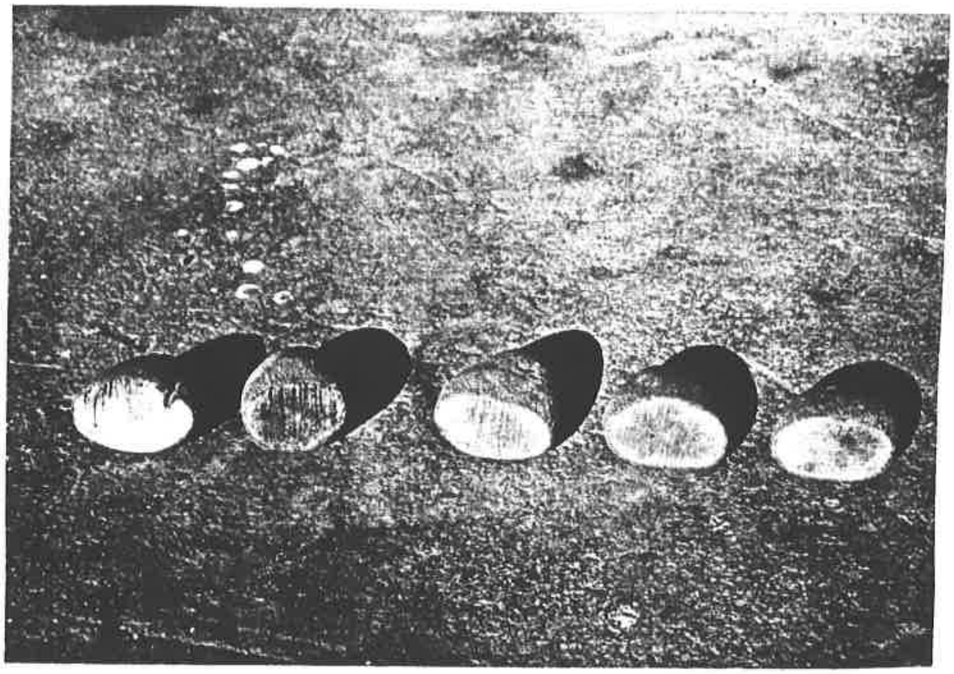


Figure 7 - Cut samples after three days in storage
5,000 psi, 7,000 psi, 9,000 psi, 11,000 psi, and control

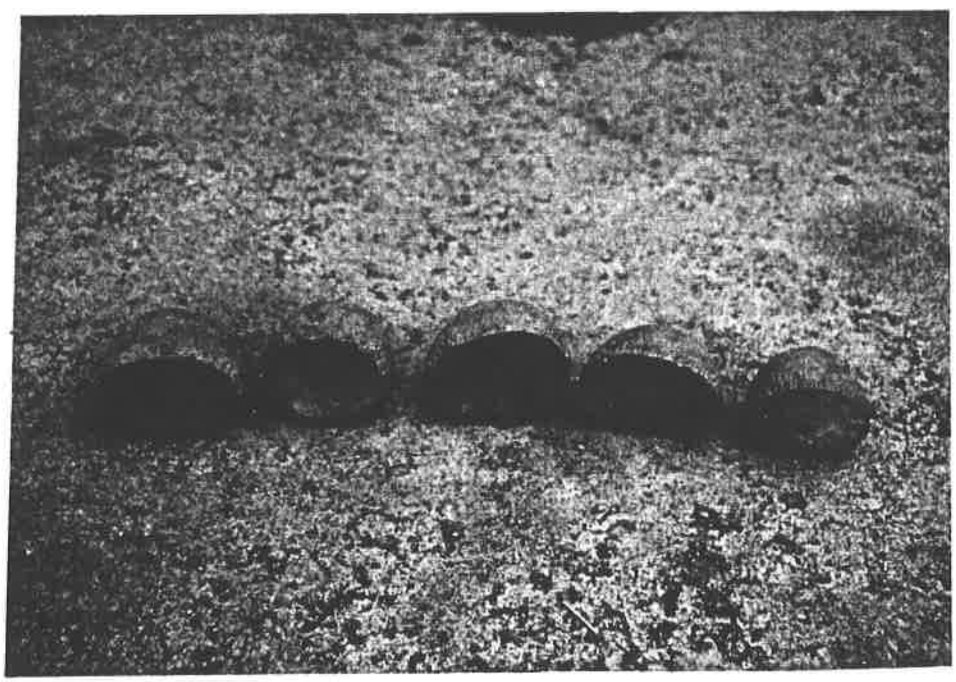


Figure 8 - Cut samples after seven days in storage
5,000 psi, 7,000 psi, 9,000 psi, 11,000 psi, and control

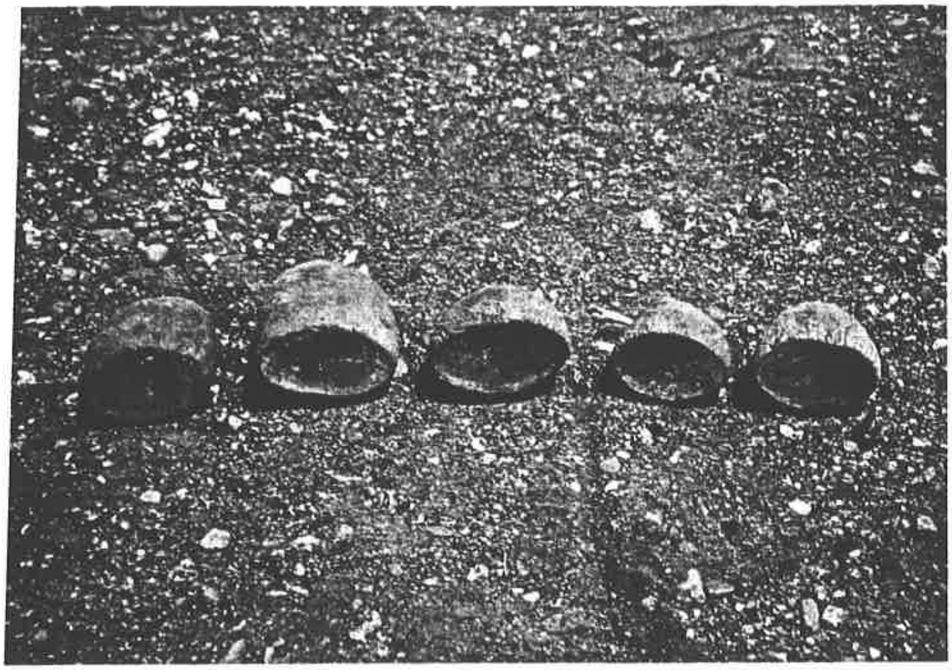


Figure 9 - Cut samples after three days in storage
5,000 psi, 7,000 psi, 9,000 psi, 11,000 psi, and control

and were shrinking around the edges. This was due to the temperature of the suberization room getting too warm. Even though the samples were turning black a tough skin was still present on the cut surface. Once again the cut samples appeared to be handling the storage as well as the control was.

The sacks were removed from the suberization room after being in there for ten days and were placed in a walk in cooler. This was done to reduce the amount of rotting and shrinking that might occur in the warmer temperature. After the samples had been in the storage for fourteen days, they were removed and weighed again. According to the measurements, each sack lost approximately one pound while in the storage. This shrinking was due to the suberization room being to warm. Once again the cut samples were looked at and analyzed. All of the samples had basically the same appearance, regardless of the pressure and the belt speed used to cut the potatoes. For the most part, they all had a tough skin formed on the cut surface. They also had some black discoloration present. It appeared that all of these samples could be planted and a healthy plant would be produced when placed under good growing conditions. The potatoes cut with the metal knives also appeared to have the same appearance as the other samples.

Each cut potato was taken and analyzed for the amount of decay that had occurred on its cut surface. In order to provide a percentage of the potato surface which had not decayed a rating was given to each potato based on the amount of the surface which was black and soft. A rating from one to five was given to each sample and recorded. A five rating was given to a cut surface where no decay was present on the cut surface. Lower ratings were given depending on the amount of decay present on each cut surface. For each pressure, belt speed combination, and the control every potato was rated. These ratings were recorded and a table was compiled. This table can be seen in the Appendix. A percentage of the healed surfaces were calculated using the ratings. Table 2 below lists the percentage of tubers that healed properly for each test conducted.

Table 2

Water Pressure (psi)	Belt Speed (f/sec)	Percent Tuber Healed (%)
5,000	0.30	95.0
5,000	0.15	96.6
5,000	0.10	91.6
7,000	0.10	95.0
7,000	0.15	96.6
7,000	0.30	92.5
9,000	0.30	95.8
9,000	0.15	93.3
9,000	0.10	90.8
11,000	0.10	95.8
11,000	0.15	92.5
11,000	0.30	94.2
Control		93.3

According to these calculations, for this test, 90% or better of the cut surfaces healed without any decay present. Most of the decay that did occur was due to the warm temperatures in the storage. It appears that cutting potatoes with a high pressure water jet will provide an antiseptic means of cutting seed potatoes and allow them to heal as well or better than the potatoes cut with metal knives

Conclusion:

In conclusion, an antiseptic potato seed cutter was designed using a water jet cutting system, for this design project. The purpose of this potato seed cutter was to reduce the spread of diseases by using the water jet cutting system rather than metal knives. Metal knives are found in most of the seed cutters that are presently being used. These metal knives have been found to spread disease during the seed cutting process. This spreading occurs when a diseased potato is cut with a knife and the knife becomes contaminated. Water jets do not become dull or contaminated, therefore, they can be used to replace the metal knives and eliminate disease spreading. Previous testing has been conducted on cutting potatoes with a water jet. It was found that potatoes could be cut with pressures ranging from 10,000 to 30,000 psi. It was important to determine whether or not potatoes could be cut using pressures less than 10,000 psi during this project. The lower the pressure, the less expensive it is to produce these pressures. It is also safer to work with lower pressures.

In order to provide a water jet cutting system, high pressures must be produced. High pressure pumps are capable of producing these kind of pressures, however they are fairly expensive to purchase and operate. It was determined that a hydraulic ram would be capable of producing high water pressures at a feasible cost. A hydraulic ram was designed, constructed, and analyzed for this research project. The hydraulic ram that was analyzed was capable of producing pressures up to 11,000 psi. A sapphire nozzle obtaining a orifice diameter of 0.010 inches was required to produce this pressure. Another nozzle having an orifice diameter of 0.014 inches was also analyzed, but was found to only produce a maximum pressure of 4,000 psi. Sapphire nozzles were used to reduce the amount of wear that occurs under high pressures. The water pressure was varied by increasing or decreasing the oil flow rate into the hydraulic ram.

A conveyor table was designed and constructed to transport the potatoes through the water jet. It was designed to provide a gap for the water jet to go through and to keep the potatoes centered on the belts. A hydraulic orbit motor was used to drive the conveyor belt and vary the speed. Through testing, it was found that if one potato was placed on to the conveyor belt it would not travel through the water jet. The single potato would begin to spin on the belts when it hit the water jets. A device was needed to help push the potato through the water jet. When testing was done several potatoes and a square metal shaft had to be placed on the belt at the same time to force the tubers through the water jet. Due to this the speed at which the conveyor table could be operated at was limited.

A stand was also designed and constructed to hold the hydraulic ram stationary above the conveyor table. It was designed so that the nozzle height could be adjusted with ease. The closer the nozzle could be placed to the potato the smoother the cut appeared to be. As the water jet traveled further away form the nozzle it began to dissipate and spread out. This caused the cut surface to be rougher on the bottom of the cut potato.

After the prototype potato seed cutter was constructed, several tests were conducted. From these tests it was determined that a potato can be cut with a water jet at a minimum pressure of 5,000 psi. When this pressure was used, the potato could be cut completely through. Any pressure under that would penetrate the potato, but not cut it completely through.

Four different pressures were tested and analyzed for this research project. At each of these pressures three different belt speeds were also analyzed. From observations made during the testing no distinct difference was seen between cutting the potatoes with different pressures. The potatoes cut with lower pressures had a rougher and more jagged cut surface. However these potatoes could still be planted and have the same success as those cut at higher pressures. Transporting the potatoes at a faster belt speed produced a smoother cut surface.

The samples that were cut were placed in a suberization room to determine the effects that cutting with a water jet would have on the healing process. The samples were looked at several times while they were kept in the storage. By looking at them, it was determined that they were healing properly. A control was placed in the storage with them to have something to compare them with. The samples appeared to be healing at the same rate as the control was. Due to the time of year that the prototype was completed the cut samples could not be planted to obtain growth and yield data.

After the samples were in the storage for two weeks they were removed and analyzed. They were analyzed by rating each cut potato on how much of the cut surface had decay on it. From this analysis it was determined that greater than 90% of all the cut surfaces had healed properly. A reason that there was some decay on the cut surfaces was due to the warm temperatures in the suberaization room where the potatoes were stored. It was also concluded that any pressures tested could still be used and still produce seed pieces that could be planted. There were no extreme effects present, of cutting potatoes with a water jet cutting system.

A water jet cutting system can be used in a potato seed cutter and still compete economically with seed cutters used today. Using a water jet will not eliminate diseases found in potato crops but will reduce the spreading of these diseases. This reduction in disease spread will increse the quality and quantity of potato production.

Recommendations:

If future work is to be done on this project there are several things that should be considered. First of all, several potatoes should be cut with this prototype and then planted in the spring allowing enough time for proper growth. A complete analysis can not be conducted on the effects of cutting with a water jet cutting system by just placing the samples in a suberization room. Planting the cut samples along with a control cut with a metal knife potato seed cutter will provide useful growth and yield data.

For this prototype potato seed cutter to compete with the potato seed cutters on the market today, the cutting capacity of this prototype must be increased. Several things can be done to increase the cutting capacity of a water jet cutting system. One way that this can be done is by designing a hydraulic ram which provides a continuous flow of water at high pressures. This may be possible by designing a double acting hydraulic ram. This double acting ram can consist of two hydraulic cylinders operating in a cycle opposite of each other. A high pressure pump is still an option for producing a continuous flow of water, if it is found that it could be afforded in a potato seed cutter. Having a continuous water jet would increase the cutting capacity of a seed cutter using a water jet cutting system.

Having a conveyor table that would align the potatoes manually would be a great asset to a water jet potato seed cutter. It would remove any human labor of setting the potatoes on the belt and would increase the safety of the seed cutter. Also designing a means of holding the potatoes as they travel through the water jet would prove to be necessary. It may be possible to hold the potatoes using two crush rollers. The potatoes could be aligned on the conveyor table then sent through the crush rollers. The crush rollers would then hold the potato in its aligned position as it moves through the water jet. The nozzles could then be arranged so that the potato could be cut equally.

References:

Becker, R. And Gray, G.M. 1992. Evaluation of a Water Jet cutting System for Slicing Potatoes. Journal of Food Science. 57: 132.

Appendix

A list of the cost and the suppliers of the parts and materials used to construct this prototype is provided in Table 1:

Table 1 -

Part or Material	Supplier	Cost
1" Chrome Shaft	Harmon Welding	$ 32.50
4" Brass Shaft	Harmon Welding	$ 25.00
11/4" Brass Shaft	Harmon Welding	$ 16.82
4" Seamless Steel Pipe	Harmon Welding	$ 23.24
2" Pump Shaft	Harmon Welding	$ 15.00
4 1/4" Steel Shaft	Harmon Welding	$ 5.00
3 1/2" Steel Shaft	Harmon Welding	$ 3.32
2" Square Tubing	Harmon Welding	$ 17.60
2"X 1/2" Steel Plate	Harmon Welding	$ 2.90
1 1/2" Square Tubing	Harmon Welding	$ 6.50
1 1/4" Steel Shaft	Harmon Welding	$ 7.08
1" Square Tubing	Harmon Welding	$ 8.40
6" X 1/8" Steel Plate	Harmon Welding	$ 7.68
2" X 1/8" Steel Plate	Harmon Welding	$ 2.58
O-ring	Center Part Store	$ 1.60
Oil Seal	Center Part Store	$ 3.60
Stainless Steel Check Valve	Monte Vista COOP	$ 41.50
Pressure Gauge	MSC	$ 47.32
Sapphire Nozzles	Stone Age Engineering	$ 46.00
Hydraulic Hoses	Center Part Store	$ 80.58
Auto Fan Belts	Center Part Store	$ 62.00
Pressure Gauge	Northern Hydraulics	$ 16.99
Flow Meter	Northern Hydraulics	$199.99
Bronze Globe Valve	Surplus Center	$ 18.99
Directional Control Valve	Surplus Center	$ 59.95*
Hydraulic Pump	Surplus Center	$170.00*
Electric Motor	Surplus Center	$309.95*
Flow Control Valve	Surplus Center	$ 59.95*
		Total: $1285.59

* These products were donated to the project, the cost listed is just the cost to purchase each of the items

Senior Design - Prototype Water Jet Potato Seed Cutter

Sample Test - 7/3/97 - cut and placed in suberization room for two weeks

nozzel size - .010 inches

Variety - Centienial Russet Burbank

Run	Oil Pressure (psi)	Oil Pressure (MPa)	Oil Flow Rate (GPM)	Oil Flow Rate (L/min)	Water Pressure (psi)	Water Pressure (MPa)	Water Flow Rate (GPM)	Water Flow Rate (l/min)	Water Thrust Force (lbs)	Water Thrust Force (N)
1	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
2	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
3	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
4	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
5	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
6	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
7	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
8	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
9	800	5.5	1.5	5.7	5000	34	0.15	0.56	0.55	2.44
10	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
11	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
12	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
13	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
14	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
15	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
16	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
17	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
18	1000	6.9	1.75	6.6	7000	48	0.18	0.67	0.77	3.41
19	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
20	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
21	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
22	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
23	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
24	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
25	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
26	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
27	1200	8.3	2.0	7.6	9000	62	0.20	0.75	0.99	4.38
28	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
29	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
30	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
31	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
32	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
33	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
34	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
35	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36
36	1400	9.6	2.2	8.3	11000	76	0.22	0.83	1.21	5.36

Cylinder Time (sec)	Belt TIme (sec)	Belt Legth (ft)	Belt Legth (m)	Belt Speed (ft/sec)	Belt Speed (m/sec)	Initial Sample Weight (lbs)	Final Sample Weight (lbs)
22	11	3	0.91	0.27	0.08		
22	11	3	0.91	0.27	0.08		
22	11	3	0.91	0.27	0.08	5	4
22	23	3	0.91	0.13	0.04		
22	23	3	0.91	0.13	0.04		
22	23	3	0.91	0.13	0.04	5	4
22	32	3	0.91	0.09	0.03		
22	32	3	0.91	0.09	0.03		
22	32	3	0.91	0.09	0.03	6	5
18	32	3	0.91	0.09	0.03		
18	32	3	0.91	0.09	0.03		
18	32	3	0.91	0.09	0.03	5	4.5
18	20	3	0.91	0.15	0.05		
18	20	3	0.91	0.15	0.05		
18	20	3	0.91	0.15	0.05	4.5	4
18	10	3	0.91	0.30	0.09		
18	10	3	0.91	0.30	0.09		
18	10	3	0.91	0.30	0.09	4	3.75
16	10	3	0.91	0.30	0.09		
16	10	3	0.91	0.30	0.09		
16	10	3	0.91	0.30	0.09	5	3.75
16	20	3	0.91	0.15	0.05		
16	20	3	0.91	0.15	0.05		
16	20	3	0.91	0.15	0.05	5	4
16	32	3	0.91	0.09	0.03		
16	32	3	0.91	0.09	0.03		
16	32	3	0.91	0.09	0.03	4	3.5
14	32	3	0.91	0.09	0.03		
14	32	3	0.91	0.09	0.03		
14	32	3	0.91	0.09	0.03	4	3.5
14	19	3	0.91	0.16	0.05		
14	19	3	0.91	0.16	0.05		
14	19	3	0.91	0.16	0.05	4	3.5
14	10	3	0.91	0.30	0.09		
14	10	3	0.91	0.30	0.09		
14	10	3	0.91	0.30	0.09	5	4.25

Senior Design - Prototype Water Jet Seed Cutter

Tuber Analysis - 7/17/97

Variety - Centennial Russet Burbank

Sample #	Water Pressure (MPa)	Belt Speed (m/sec)	Tuber Decay Analysis Rating Tuber # 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total	Percent Tuber Healed %
1	34	0.08	3	5	5	5	5	4	5	5	5	5	5	5	5	5	4	5	5	5	4	5	5	5	5	5	114	95.0
2	34	0.04	5	5	4	5	5	4	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	4	5	5	116	96.6
3	34	0.03	5	5	4	5	5	5	5	5	5	4	4	4	5	5	5	3	5	3	5	5	5	4	5	4	110	91.6
4	48	0.03	5	4	5	5	4	5	5	5	5	4	5	5	5	4	5	5	4	4	5	5	5	5	5	5	114	95.0
5	48	0.05	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	3	4	5	5	5	5	4	5	5	116	96.6
6	48	0.09	5	4	4	5	5	4	5	5	5	4	4	5	5	5	5	5	4	5	3	5	5	4	5	5	111	92.5
7	62	0.09	5	4	5	5	5	3	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	115	95.8
8	62	0.05	5	5	5	5	5	5	5	4	4	5	5	3	4	5	5	5	5	4	4	5	5	5	5	4	112	93.3
9	62	0.03	5	5	5	5	3	3	4	4	5	4	5	5	5	5	5	5	5	4	5	5	5	5	4	4	109	90.8
10	76	0.03	5	5	5	5	4	5	5	4	5	5	5	5	5	5	5	5	4	5	5	5	5	5	3	5	115	95.8
11	76	0.05	5	5	5	3	5	5	5	3	5	5	5	4	5	5	5	5	5	5	4	3	4	5	5	5	111	92.5
12	76	0.09	5	4	5	5	5	4	4	5	5	4	5	5	5	5	4	4	5	5	5	5	4	5	5	5	113	94.2
Control			5	5	5	5	4	3	5	5	5	5	5	5	5	4	3	5	5	5	5	5	5	5	4	4	112	93.3