SEPARATION OF STONES AND SOIL CLODS FROM POTATOES

Submitted to: Department of Agricultural Engineering

Submitted by: Wayne Wood

Date submitted: March, 1978.

TABLE OF CONTENTS

A C K N O W L E D E M E N T S

I would like to thank Mr. Winston Wood of the Fruit and Vegetable Inspection Division of Canada Department of Agriculture in P. E. I. for the information he acquired from potato producers and made available to me for the purpose of this report.

I also thank Mr. D.C. MacRae of the Scottish Institute of Agricultural Engineering for answering my request on developments of separation equipment in England.

Special thanks go out to Dr. Beveridge of the Food Sciences Department of MacDonald College for the use of his lab facilities and for the information regarding the Spectrophotometer and how to get the best results from it.

I would also like to thank Prof. G.S.V. Raghavan, of MacDonald College Agricultural Engineering Department, my staff advisor for this project, for his help in the development of this project. Thanks too for the graphs that were not in published literature regarding the results obtained by Story and Halloway (1969).

Thanks go also to Linda Reader for typing this paper.

ABSTRACT

Potato producers have always been faced with the problem of the removal of unwanted debris from potatoes during the harvesting process. Methods of separation using differences in a physical property between the potatoes, stones, and soil clods such as specific gravity, shape, spectral reflectance of light, hardness or electrical resistance which have been tested experimentally or have become commercially available are discussed.

The reflectance properties for samples of Prince Edward Island produced potatoes were measured for wavelengths of light from 0.4 to 0.88 microns using a Spectronic 20 spectrophotometer. This was done to determine whether or not a separator which used the difference in light reflectance between stones and potatoes would be applicable to Prince Edward Island conditions.

The potatoes from which the data was obtained showed similar spectral reflectance characteristics to other researcher's data up to a wavelength of 0.74 microns. The reflectance of these samples decreased more rapidly above this wavelength due to the limited range which was accurately measured by the machine. Before a positive conclusion could be reached, further tests would have to be performed using a spectrophotometer with a greater range in the infrared region.

LIST OF FIGURES

INTRODUCTION

Potato production represents a large percentage of the agricultural production of Prince Edward Island. Each year an average of 40,000 acres are grown to be sold for either seed or table stock, outside the province. Many of the producers plant in excess of two hundred acres and often depend on one harvestor to dig the crop over the harvesting season. This season may start as early as mid-August and the harvestors are used on a daily basis to gather the complete crop before the ground freezes later in the fall.

Unfortunately, the potato harvestor is following the same trend as other farm implements in betterment of the design of the machine. Few improvements have been made with respect to removing some of the manual labor required for the harvesting process. The manual labor to which reference is made here is that which is required to remove stones and soil clods from the flow of potatoes on the harvestor which is directed to transport trucks.

Stones cause mechanical damage to the tubers during crowding on the conveyors and also each time the masses of material are dropped from one conveyor to the other during the conveying process.

Although Prince Edward Island producers are not plagued with the intensity of stones encountered by producers in other major potato growing areas such as New Brunswick and Maine, still there is a need to have four people on the harvestor to remove the stones, soil-clods, and other materials such as vines that have found their way through the system of conveyors. The cost of this labor during the 1977 harvesting season was $4.00 per man's hour or $16 per hour. The extra production cost due to this labor cost was 8.5¢ per 100 pounds of potatoes based on an average production of 300 cwt. per acre and at a harvesting rate of one acre per hour. If three of these people could be replaced by a machine which could remove the unwanted debris for a reasonable overhead cost, it would be a great step in the machinery industry and it would make the production of this crop more efficient.

The purpose of this project is to analyze the methods which have been experimented for stone and soil clod removal and to study the spectral reflectance properties of potatoes produced on Prince Edward Island to determine whether or not a system which used this characteristic as a means for separation could be used by the potato producers of Prince Edward Island.

LITERATURE REVIEW

The operating potato harvestor picks up the mound of clay in which the potatoes grow, and passes it over a series of chains and conveyors during which time the loose clay should be shaken through the spaces in the chain conveyor, along with all other particles with a diameter less than 1.5 inches. The materials which fall through the chains are deposited back onto the field. The vines stay on a sloped conveyor which deposits them back to the field while the potatoes, with unbroken soil clods and rocks, are deposited to a cross conveyor which in turn takes them to a sloped side elevator. The side elevator (conveyor) deposits the potatoes and whatever other materials still remain with them onto a conveyor bed that transports the tubers to the bulk box. It is on this last conveyor that the hand sorting is carried out.

Design Parameters:

When choosing a sorting system, it is best to determine its suitability for the job. Some of the major points to keep in mind when picking a system are:

(1) Rate of work. A large number of relatively large size of objects are going to be handled per unit of time. Sides (1974) estimated as many as 120,000 potatoes may be passed over the harvestor per hour while Gray et al. (1972) based their separations design on a potato unit flow rate of 160,000 per hour. Story and Raghaven (1973) designed for a flow of 500,000 potatoes, stones, or soil clods per hour.

(2) Variations of soil amount, moisture and aggregate size.

(3) Moisture and the soil attached to the tubers and stones.

(4) Ability of the separation mechanism to work in the presence of a small amount of organic material.

(5) Susceptibility of the crop to damage.

(6) Similarity of stones and tubers in several properties: weight, shape, colour.

(7) Miscellaneous- variations within and among areas and incidents due to field operations.

With this list of problems in mind a system has to be designed. The requirements would be:

(1) A consistant difference in one or more of the properties of the materials to be separated.

(2) The objects to be sorted to be arranged in some manner so that each object may be analyzed independently.

(3) The means by which the potatoes are to be separated has

to be non-destructive to the potatoes and has to work under a variety of field conditions.

(4) The separation system should not cost more than the available manual labor would for the estimated lifetime cost of the mechanism.

SPECIFIC GRAVITY SEPARATORS

Inclined Conveyor: One of the first attempts to separate stones from potatoes was to pass the materials on a conveyor operating at an inclined angle which was large enough to cause the more round potatoes to roll down while the flat stones remained to be discharged from the harvestor. For its simplicity, the system worked moderately well until the invention of the two row harvestor. Due to the increased flow of materials and additional crowding, the potatoes tend to stay on the conveyor and are discharged with the stones. (Sides, 1974).

Air Separator: A separation system now being used in Maine (Sides, 1974) is one using an air blast or a vaccuum which lifts or blows off the less dense potatoes from the conveyors, leaving the more dense and other materials to be discharged back to the soil. The air blast and vacuum are caused by a large centrifugal fan which is run by an auxillary engine. The potatoes are lifted or moved because they have a lower specific gravity and thus lower terminal velocity than the stones.

This method works reasonably well in the presence of a high ratio of potatoes to stones, 19:1, with a separation efficiency of 97% using flow rates of material from 500 to 1500 pounds per minute. When the ratio of potatoes to stones drops to 2.33:1, the separation efficiency drops to 90%. These values were obtained after the machine was adjusted for the conditions. The increase in the flow rate of stones, however, did cause a substantial decrease in the efficiency of the machine.

These machines do cause an unfavorable amount of mechanical damage to the potatoes, notably when the air velocity in the chamber is too high. The recommended air velocity of 100 feet per second in the chamber was found to be too high. The reduction to a velocity of 95 feet per second reduced damage losses.

The installed unit put an additional cost of $5000 on a harvestor in 1968. The engine, to provide the power for the air stream, can consume as much as 30 gallons of fuel for an eight hour work shift.

Potato production studies in New Brunswick have shown that harvesting rates are increased using the air vacuum attachment for separation. Harvesting rates could be increased from 0.68 acres per hour using a conventional harvestor to 0.89 acres per hour with the harvestor having the separation unit.

Flotation Separator: In the early 1950's, the Shotbolt harvestor was developed in England which used a tank of water as a separation mechanism. In this tank, the potatoes would float while the stones and soil clods would sink. The potatoes were taken off the top and the stones and other particles were continuously scraped from the bottom. The separation percentage was excellent but the potatoes tended to be more susceptibile to breakdown in storage after being wet.

Rotating Brush Separator: Separation was also attempted by passing the materials onto a rotating brush. The more dense particles tend to penetrate the bristles more than the less dense potatoes. When adjusted properly, the less dense potatoes should remain on top of the brushes while the stones and soil clods being more dense, should pass through and be deposited on the ground.

Tests on the rotating brush model showed that the separation worked for systems which had specific gravity ratios of 2.5:1. The efficiency of operation did not depend on brush speed, loading rate or separation slope. Brush spacing appeared to be the only significant parameter for the operation.

The capacity of a 60 inch wide model separator was found to be sufficient to handle the output of a two row harvestor travelling at 1-1/8 mph in a crop yield of 300 cwt per acre. The prototype was tested using a potato to stone ratio of 1:1 by weight. (Eaton, 1969).

The proper length, size and type of bristle was not established. The prototype was never tested using actual field conditions. The suggested positioning of the unit was directly after the potatoes fell from the main digger chain.

ELECTRONIC CONTROL SEPARATION

Electrical Resistance Separator: Other separation mechanisms have been designed to analyze a specific difference on a property of the potatoes, stones and soil clods. The electronic interpretation of the signals received, controls a sorting gate which the object must pass.

Gilmour (1960) tried to develop an Electronic Potato Screener. He concludes:

"This method works on the difference in electrical resistance between a pair of blunt electrodes and are simultaneously applied to the material being tested. The resistance between the blunt pair, when applied to a potato, will be about 50 kilo ohms or more, depending on the dryness of the skin. The resistance of the wet clod will be less than 50 kilo ohms, but dry clods and stones will have much higher resistance. The resistance between the sharp electrodes whenapplied to the potato will be high at first, but will fall to a value of 20 to 30 kilo ohms when the skin is pierced. This value is remarkably constant from potato to potato. Clods and stones will give a much higher resistance between the sharp electrodes than between the blunt ones, for the area of contact is less. Thus, we distinguish between a potato and any other object, for only with a potato will the resistance between the sharp electrodes be less than between the blunt ones".

The mechanism works with an accuracy of 90% and seldom less than 85%. Because the skin punctures are so small, there will be no mechanical damage to the tuber.

The system was never tested under field conditions. Data is available from lab tests only. The major disadvantage is that all four electrodes must make good contact with the surfaces, otherwise the resultant signal could lead to the false acceptance or rejection of an object. The actual rejection mechanism is not well described nor is the method of obtaining individual presentation of the sample.

Hardness Separator: Gray (1972) designed a system which sorted the potatoes from the stones by interpreting the vibration caused when the object was dropped from a known height onto a steel plate. Individual rows were made of the material on the digger chain by using a series of rubber channels on the chain. This conveyor chain was geared to travel 20% faster than the feed chain in an attempt to achieve better singularity of the individual objects. When the potato or stone comes to the end of the conveyor, it falls 9 inches onto a sloped steel plate. The frequency of the vibration caused by the impact is measured by an accelerometer which then feeds the signal to an input amplifier. If the frequency is high enough, it means that the object which dropped on the plate is a stone. A signal which controls the circuit is sent out and the circuit activates to open a sliding gate discarding the stone to the ground.

The frequency and amplitude of the vibration caused when a potato strikes the plate is much lower than that for a stone, thus the gate will not be opened.

Stones from 1.5 to 2.5 inches in diameter are large enough to trigger the mechanism. This size is small enough because any that are smaller than this should pass through the chains of the conveyor.

Dropping objects onto the sensor offers advantages such as;

(a) it could be easily incorporated onto a conventional harvestor at the intersection of two conveyors; (b) fixed drop heights could be maintained, thus allowing predictable response upon impact; and (c) the rebound trajectory could assist in the separation since the gravitational forces could move the stone through the gate. The capacity of the steel plate sensor was approximately 20 stone impacts per second since the vibrations were damped out within 50 milliseconds. The output voltage from the amplifier to the switching circuit lasted for only 5 milliseconds.

The capacity of the system was limited by the time required to run the gate through a complete open and close cycle. It took about 0.2 second, therefore it could react for 5 objects per second. Consecutive stones at a rate of more than 5 per second kept the gate open continuously.

This machine was tested in the field. The major problem that occurred was that the sorting gate failed to operate when there was soil build-up around it. Each plate had to be mounted separately on the frame with padding to prevent stray vibrations from triggering other sensors when a large stone hit one of the plates. The mechanism did register all stone impacts. No further information is available on this method except that it is in use on a stationary processing line (Gray, 1972).

<u>X-Ray Separator</u>: The only commercially available and well established electronic separator in the world is the X-ray harvestor which is in use in the United Kingdom. In the United Kingdom, a large number of X-ray separators are now in use fitted

to a Hestan (formerly a Whitsed) harvestor and on the Lockwood static separator. (MacRae, 1978).

The unit works on the fact that X-rays pass through the carbon, hydrogen and oxygen of the potato but they are hindered by the silicon in clay and stones. A sensor is used to collect the ray transmitted and it controls a mechanical separator which is moved out of the way of the falling stone.

The English X-ray machine is designed for a crop production of 70,000 potatoes per acre and a harvesting rate of 3 acres per 8-hour day. This is somewhat less than the restrictions placed on the North American machines.

This unit has 24 X-ray sensors and a bank of 12 singulators. Each sensing device is set to operate at 8 cycles per second. The power required to generate the X-ray is 250 volts at 50 Hz. The sensors and activators are powered by air supplied at 80 pounds per square inch. This machine removes all the stones but it leaves a large number of small clay particles which are too small to be sensed by the X-ray (Palmer, 1973).

A prototype separation mechanism was constructed by Story and Raghavan (1972) which used the difference in the light reflectance properties of potatoes from stones and soil clods for a specified wavelength. This uses the principle given by Story (1973): "Reflectance tests on living plant materials show that in most cases, reflectance is low for wavelengths less than 0.6 micron, high for wavelengths 0.7 to 1.4 microns, and low for wavelengths above 1.5 microns".

Originally, Palmer (1961) did a series of tests on the reflectance properties of potatoes, stones and soil clods to find a range of wavelengths from which the potatoes and the other materials differed significantly in the amount of light reflected. He observed that the red brightness, the amount of light reflected between 0.8 and 0.9 micron, of all types of soils,was much less than that reflected by the potatoes. He noted not only that the brightness was affected by the reflectance of the object, but also by its size, shape and gloss. He found the effect could be reduced by reducing the field of the sensor.

Palmer (1960) found, however, that he obtained more promising data for a difference in reflectance when he used the "red-blue ratio". This was the ratio of the energy reflected between 8000 and 9000 Angstroms to that energy reflected at 3250 to 4000 A^0. He was able to distinguish between the potatoes, stones and soil clods even when the potato was almost totally covered with dirt.

When Palmer (1960) used the red brightness as the separation criteria, he found that his sensor could not distinguish between small potatoes and soil clods. When he used the red-blue, he found that he obtained almost 100% separation.

Story (1969) did tests on several varieties of soil, stones and potatoes and observed that the amount of light reflected by potatoes between 0.6 and 1.3 micron wavelength range was continuously much higher than that reflected by the stones and clods. Results of some of his tests are shown in Figures 1-3. Using this difference in reflectance, he constructed a prototype to perform the separation operation.

The sorting system which was designed for the purpose of sorting by infrared reflectance had greater design parameters incorporated into its structure than previously tested systems. It was attempted to make this system capable of handling and correctly sorting of 500,000 objects per hour.

It was proposed that the mechanism could be installed on a conventional two row harvestor immediately behind the main soil separating chains. The overall width at this point of the conveyor carrying the materials is 60 inches. The proposed width for a 14 channel separator was 56 inches. In order to install the mechanism, the collecting conveyor was moved toward the rear of the harvestor. The feed end of the side elevator which carried the potatoes to the upper level had to be extended.

The channelling conveyor, which was responsible for presenting the objects individually to the sensor, consisted of 14 troughs formed by V-belts running inside a metal trough. The belts were run at the accepting end of the conveyor by a 6-inch diameter wooden roller with grooves cut into it to accommodate the V-belts. At the end where the sensors were located, were the belts on 6-inch diameter sheaves for the outer ones while the two at the centre of the trough ran on 2-inch diameter sheaves. The velocity of the channelling conveyor was approximately 1.5 times the velocity of the digger chain. This was recommended in an attempt to keep the objects on the separating conveyor well distributed, and prevent crowding. A diagram of the channelling conveyor is shown in Figure 6. This shows the position of the major units in the system.

Each channel was required to have its own electro-optical assembly of gates, sensors and required electronics which controlled the current to the solenoids which in turn controlled the air flow to the pneumatic activating cylinders that operate the sorting gates.

The photo-conductive cell used as an optical unit which had lead sulfide detectors with a range of 0.6 micron and greater. The light sources were 12 volt tungsten filament lamps. Each photo cell contained two lead-sulfide detectors. The amount of light energy which hits either detector is a function of the amount of light reflected and the wavelength it is being transmitted. This in turn controls the circuit which controls the position of the gate.

The normal position for the separating gate is in the open position so that it allows the undesired material to fall off. If a potato is sensed, the gate is closed and guides the potato to the cross conveyor and on to the truck.

The gate has an average period of 0.344 second. It is operated by a cylinder moved with an air pressure of 150 psi. The bore of the cylinder used was 1.125 inches with 2-inch stroke.

Even though the cylinder has a fairly long period for a complete cycle, its capacity is greater than it appears. If more than one potato is sensed in succession less than 1/8 of a second apart, the gate stays closed. Experimental tests and high speed photography showed that the mechanism would have a capacity of 292,320 objects per hour for a 14 channel system.

The power for the electrical system was supplied by 115V a-c aV-va alternator. This power could be rectified to operate the 12V tungsten filamnent lamps.

The air pressure for the gates was supplied by a compressor with a capacity of 8 cfm through a pressure tank. This was operated with a small piston engine.

The authors estimated the cost of the separation unit to be at $5000 with a possible $200 a year in expenses. It was considered that it would still be necessary for one man to remain on the harvestor besides the operator, during field operation.

One problem with the system was that the electronics were sensitive to temperature changes. The photo-cells required frequent adjustment. Also, heating of one of the elements in the electrical circuit caused the solenoid to remain in a position which kept the gate closed.

Extensive tests were never carried out on the machine. Therefore, experimental data regarding the field performance of the machine was not available.

ROCK REMOVAL

A possible resort to the stone problem would be to remove the stones from the field using one of the mechanical rock pickers or rakes which are available and crushing these rocks into smaller particles of less than 1.5 inch in diameter. These practices lend themselves to some criticism as found by studies carried out in Maine and other rocky areas. Removal of the stones increased the incidence of erosion of the soil. This was not as evident when the stones were crushed and left in the soil.

Conclusions of the tests carried on over a three year period showed:

1. All stone removal reduced crop yield.
2. Bed cultures produced lower yield.
3. Cultivation of beds produced clods which could not be removed later.
4. All stone treatments were successful in reducing stones at harvest.

CONCLUSION

From the literature cited, it is seen that only two products have been made commercially available for the mechanical separation of potatoes from the stones and the soil clods. These are the methods of air separation and X-ray separation. Both of these systems work, the latter much better than the first, but both are missing numerous qualities which are important to a good separation system. Both of the systems are expensive to purchase and to operate. The air separator causes mechanical damage to the tubers without performing a perfect separation. An air separating unit purchased by an Island producer for the 1977 harvest season did not perform satisfactorily with the Island soil conditions.

The X-ray unit has not as yet appeared on the North American market. There was no literature cited stating that the unit had been experimented with on this continent. This unit is expensive because of the equipment required for the gamma rays and the sensors required for interpretation. The design parameters for this machine are low in comparison with the North American harvesting demands.

The rotary brush system has never been attempted on a commercial harvestor under natural harvesting conditions. The design is simple and the theory is promising. However, the question arises as to how to prevent the build-up of clay on the brushes. The author makes no gesture as to the life of the material in the brushes or to their performance under long tests in actual field conditions.

The impact device shows promise for efficiency in the future if it were further developed to remove the imperfections which were experienced in the initial tests. This method does show a tendency to become relatively more expensive than the method of using the infrared light reflectance. In order to have enough capacity for a maximum flow of materials, the unit would need 12 to 15 channels. The accelerometers and amplifiers alone for this many channels could possibly exceed the cost of the harvestor. This would not be too bad if the separation unit had a life expectancy much longer than the harvestor and the unit were designed to be transferred from one harvestor to another without a great deal of difficulty.

The sorting system using the infrared light reflectance appears to be the most favourable of the systems developed. Although it has never been tested on a field harvestor, its operation system appears best to fulfill the requirements of an ideal separator required for Prince Edward Island producers' needs. The system is designed for a high capacity for separation, does not inflict any mechanical damage to the tubers, has a cost which does not appear to overrun the cost of the available manpower, and it could be made transferable from one harvestor to another with a few modifications of the present design.

OBJECTIVES

The purpose of the experiments carried out in conjunction with this project was to determine whether or not the spectral reflectance properties of potatoes produced in Prince Edward Island soils exhibit the same peak reflectance properties as those potatoes tested by Palmer (1960) and Story (1973) in their experiments. The reason for doing this was to show that the same mechanism for separating the unwanted materials from the potatoes could be used in Prince Edward Island without having to make adjustments with respect to separation criteria.

Unfortunately, due to the time of year during which the experiments had to be performed, it was impossible to obtain freshly harvested samples of P.E.I. potatoes. A comparison of the spectral reflectance of stored potatoes as opposed to freshly harvested samples is shown in Figure 2.

EXPERIMENTAL PROCEDURE

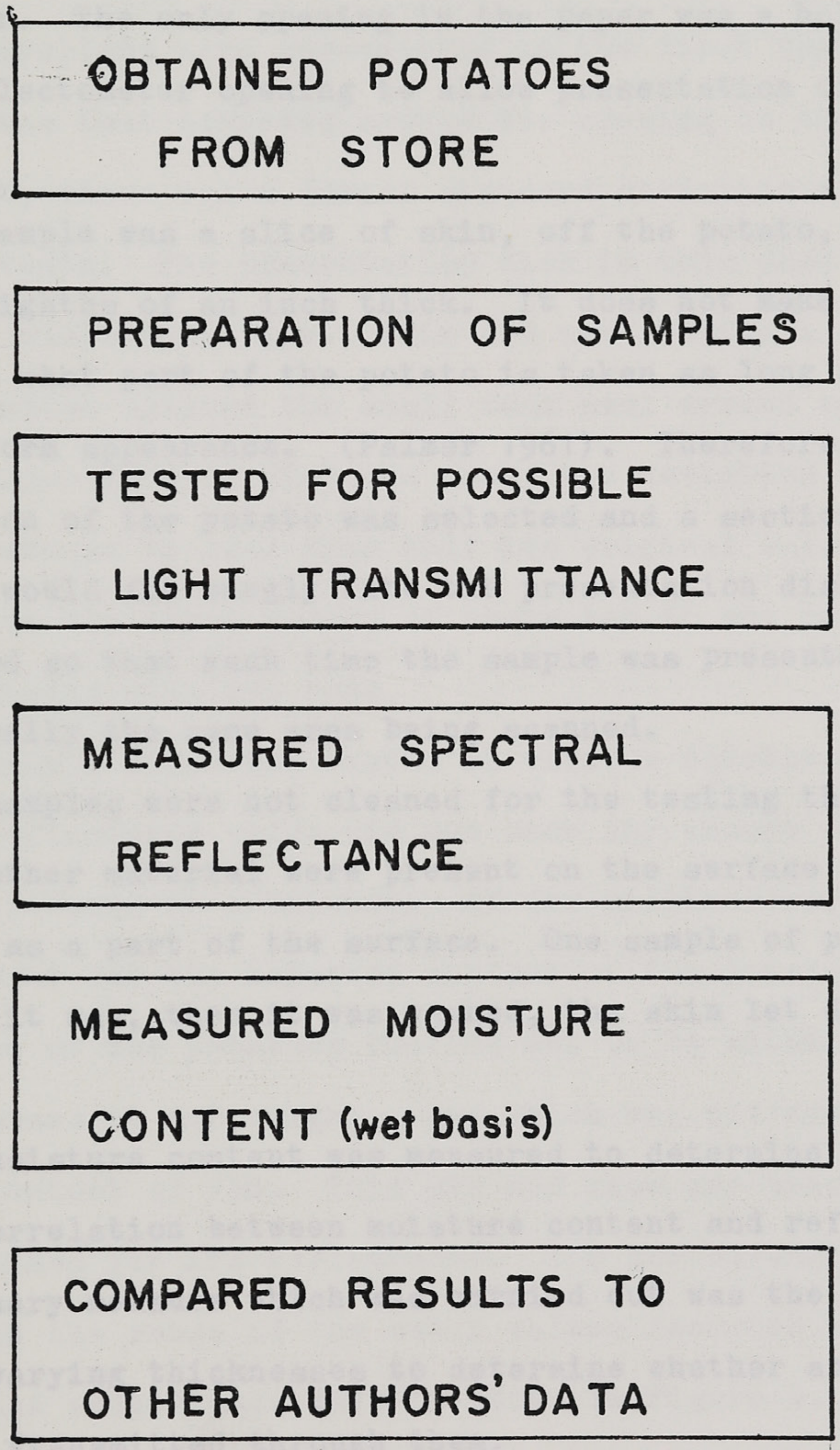
Different samples of potatoes produced in Prince Edward Island were purchased at a local supermarket. Samples were taken from different producers so that there was a better chance of obtaining potatoes produced in different soil conditions. Each sample was kept separate during testing and the reflectance data of each individual potato was recorded.

The reflectance tests were performed using Spectronic-20, spectraphotometer equipped with a spectral reflectance measuring unit. Reflectance measurements were taken over a range from 0.45 to 0.880 micron. The internal size was 0.020 micron.

The instrument had to be calibrated at each change of wavelength using a block of magnesium carbonate. With this set on the opening to the reflectance apparatus, the meter was set to full scale. The block was removed and the cap for the opening was closed. The inside of this cap is also white. The reading obtained for this cap after the meter was calibrated represented perfect reflectance. The readings obtained for the potato samples were calculated as a percentage of the reading for the cap and this was said to be the percent reflectance of the object. As may be seen, the procedure for taking a large number of readings is slow and very time consuming.

The whole potato could not be placed on the opening of the reflectometer because of the dirt it held and its inability to make a perfect seal to prevent outside light from entering the

EXPERIMENT FLOW DIAGRAM



apparatus. This outside light caused readings which were inaccurate. The sample had to be presented in a petri-dish covered with black paper. The only opening in the paper was a hole of the size of the reflectometer opening to allow presentation of the sample.

The sample was a slice of skin, off the potato, one quarter to three eighths of an inch thick. It does not make any difference what part of the potato is taken as long as the surface is of uniform appearance. (Palmer 1961). Therefore, a relatively flat portion of the potato was selected and a section was taken off which would fit snugly into the presentation dish. A snug fit was desired so that each time the sample was presented, it would have basically the same area being scanned.

The samples were not cleaned for the testing thus, whatever dust and other material were present on the surface were allowed to remain as a part of the surface. One sample of potato was first tested as it was, then it was washed, the skin let dry, and tested again.

The moisture content was measured to determine whether there was any correlation between moisture content and reflectance. A precautionary measure which was carried out was the testing of slabs of varying thicknesses to determine whether any of the light was being transmitted through them.

There was no difference in the reflectance due to varying thicknesses. Even when the piece was a sliver about a few millimeters thick, the reading did not change.

RESULTS AND DISCUSSION

Some problems were encountered in the first few tests. The major one was that achieved around the opening to the reflectometer. As a result, there was a larger standard deviation about the mean for these tests. The presentation dish in this case was covered with black electrical tape. This did not provide a smooth surface to be presented against the small foam seal around the hole. When the paper covered dish was used, the deviation about the mean was reduced to less than half its original value. It was over 10% for the first series of tests but it was reduced to 5% when the second dish was used.

The sample which was tested at various thicknesses showed that the reflectance value did not show any change even when the piece was reduced to a thickness of few millimeters.

The test for the moisture content of the potatoes showed all but one of the potatoes checked not to be within ± 1% of 80% moisture based on wet weight. One which was different had a moisture content of 75%. This did not show any bearing on the value obtained for its reflectance. Its corresponding values were within the range of the other values recorded.

Plotted reflectance data is shown in Figure 4. It shows the washed potatoes to have a higher reflectance than the unwashed samples.

Figure 5 shows a plot comparing the values of Story's results for dehydrated potatoes and the values obtained for the tests performed on the supermarket samples. It shows the values being close together up to .740 micron reading where the values obtained from the experiment decrease quickly for a short change in wavelength.

CONCLUSIONS

The results of the experiment when compared to results obtained by Story (1969) showed that the spectral reflectance of the potatoes obtained from the supermarket had much the same reflectance characteristics as was shown by Story for potatoes which had become slightly dehydrated.

The readings taken for wavelengths up to 0.74 micron followed the pattern of reflectance but above this wavelength, the reflectance of the potatoes shows a rapid decrease which does not occur for Story's data. This discrepancy was due to the inability of the machine to take accurate measurements in this region.

When the Fisher Company which sells the Spectronic 20 was contacted, the proper information as to the exact range of the reflection measuring instrument could not be obtained. The manual also provided no answer to the question.

It is safe to say that the P.E.I. potatoes do show a peak reflectance similar to those shown by the other researchers, but it cannot be stated for sure that the reflectance stays as high over the same wavelengths. It would not be safe to say that enough tests were carried out over sufficient wavelengths to state that the system designed for infrared sorting of potatoes from soils and clods could be used for Prince Edward Island conditions operating on the same wavelengths.

R E M A R K S

The potato industry does require some sort of mechanism for sorting the junk from the potato flow on the harvestor. Some machines have been experimented with in the lab and on the harvestor. Only two have been made commercially available. A couple of others showed promise; the rotating brush method, and the electronic sorter.

The infrared sorter showed promise but further work needs to be done.

The rotating brush system should be tried on a harvestor. The system showed separation efficiency of 85 to 90%. This unit is simple in its design and operation. It is amazing that this system was not further exploited.

The present author would like to do further tests on the brush type system to explore its application on the potato harvestor. Field tests and economical feasibility will be included.

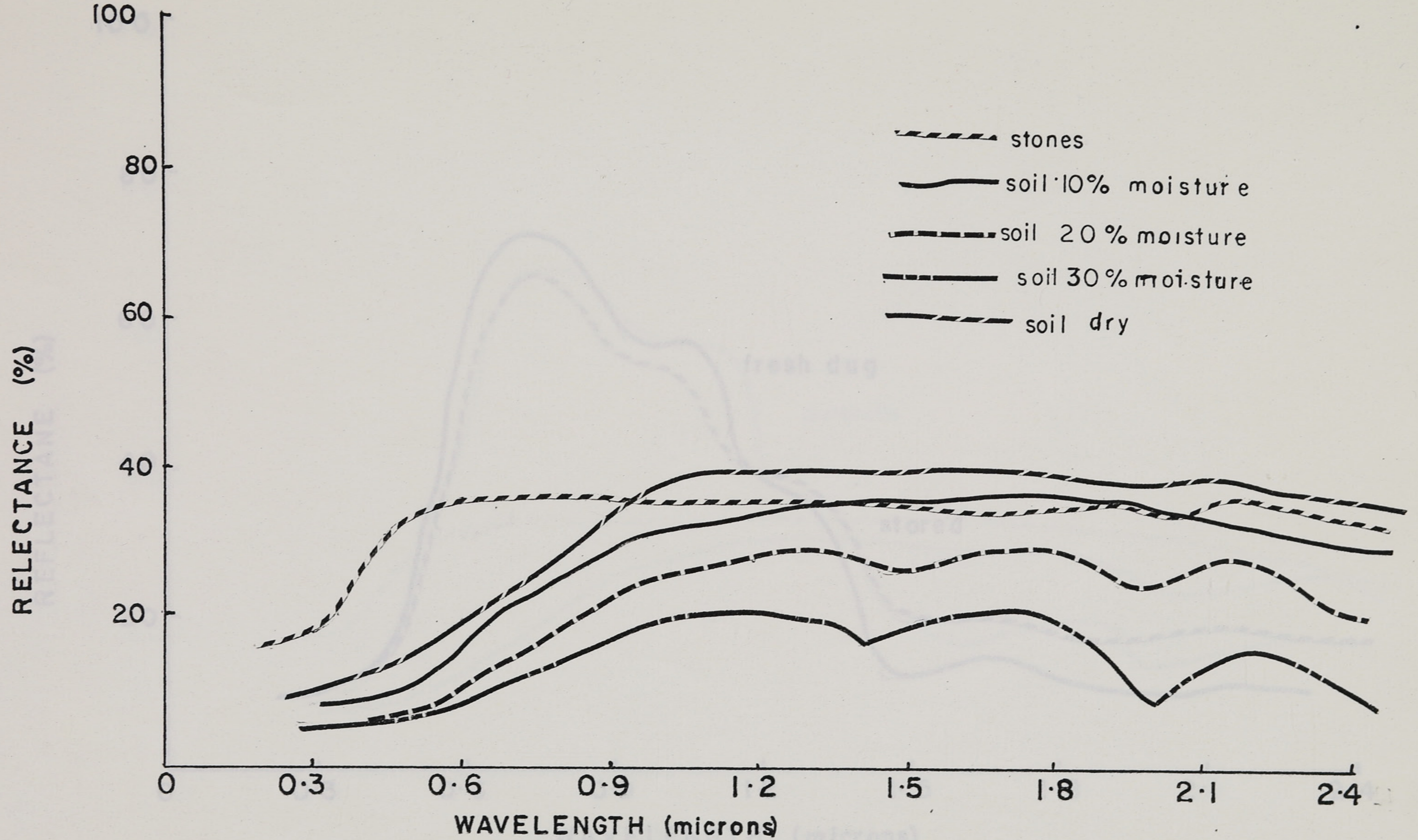


FIG I MEAN SPECTRAL REFLECTANCE OF ROCKS AND SOILS

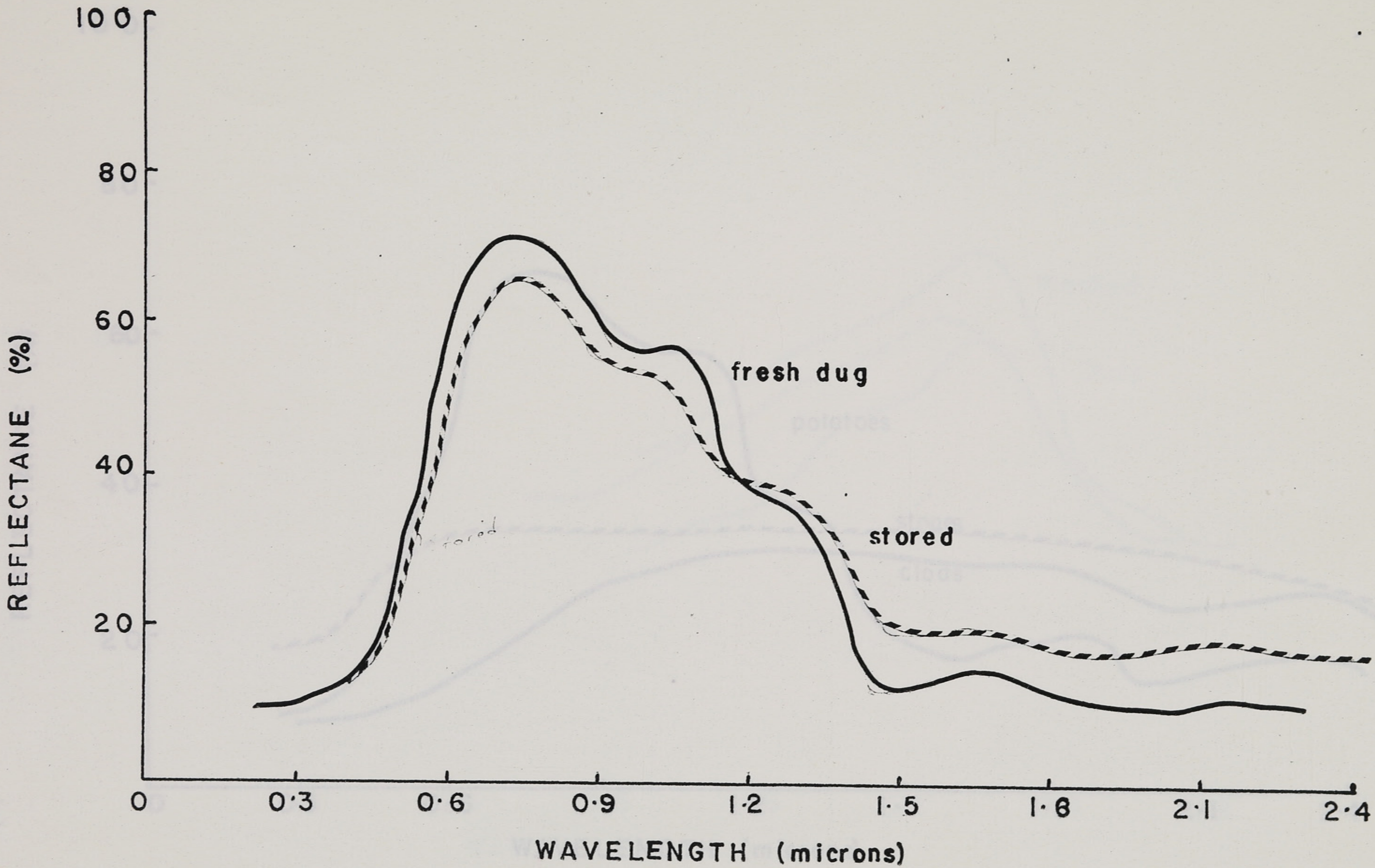


FIG 2 SPECTRAL REFLECTANCE OF POTATOES

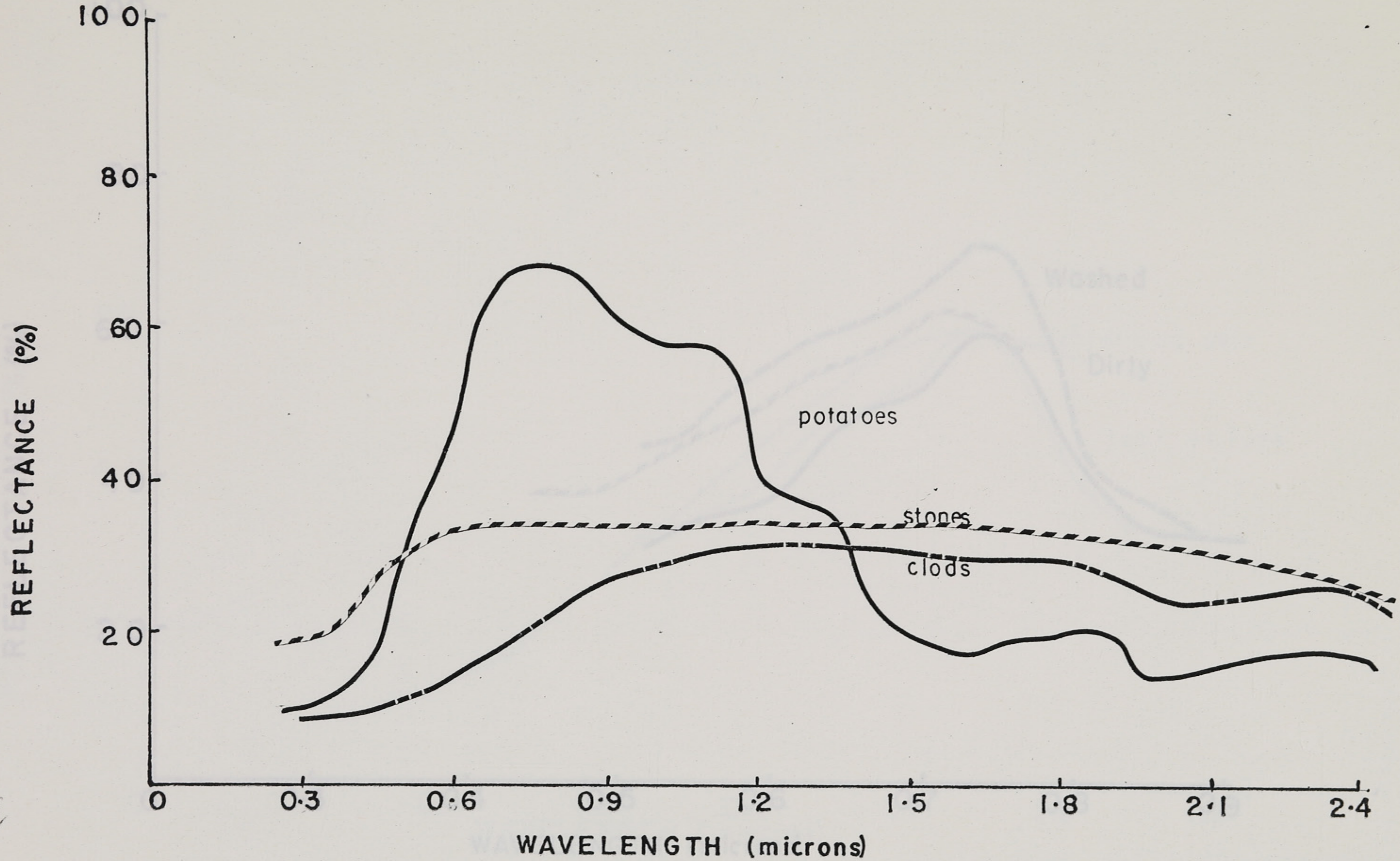


FIG 3 SPECTRAL REFLECTANCE OF POTATOES, STONES, AND SOIL CLODS

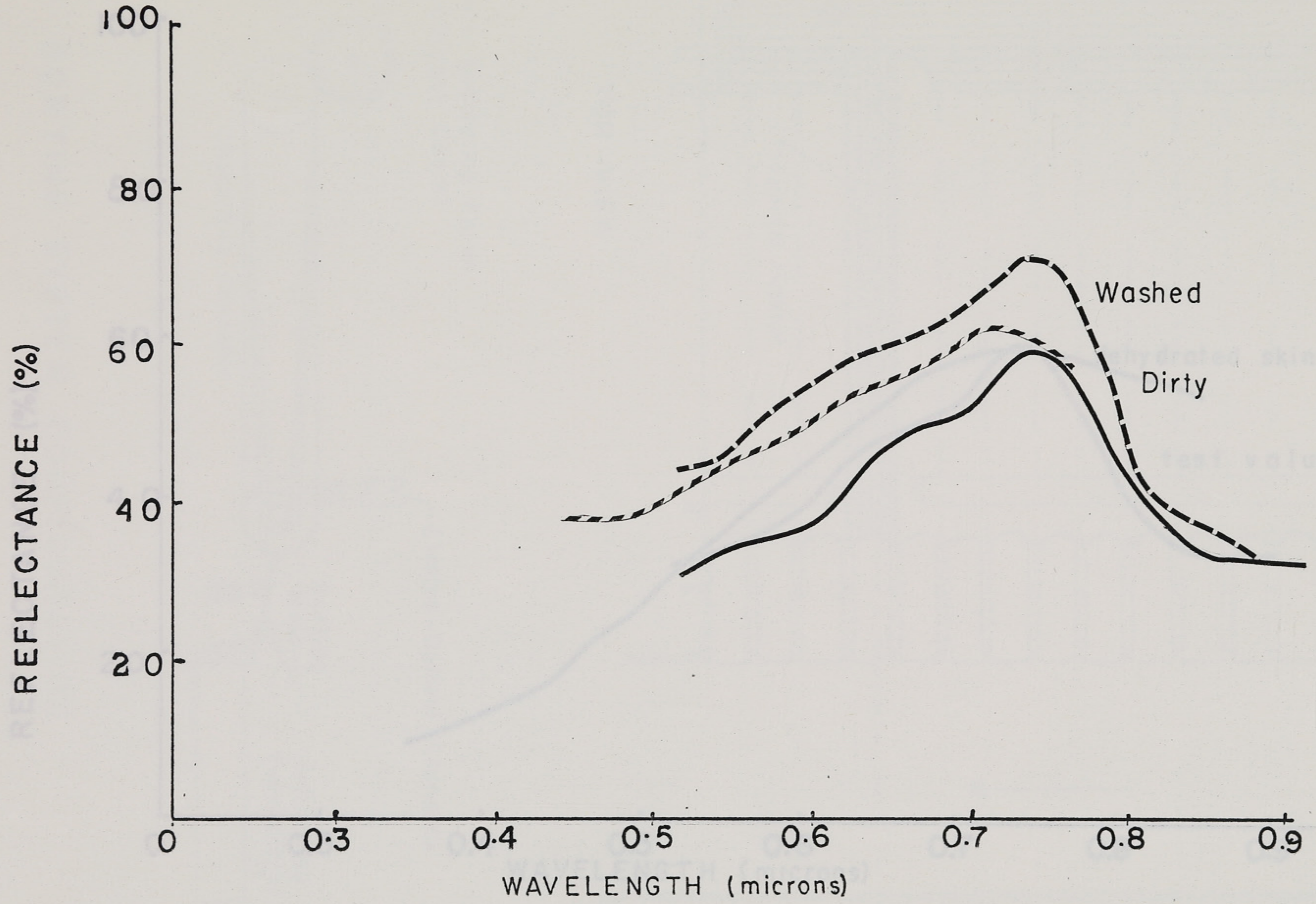


FIG 4 SPECTRAL REFLECTANCE OF P. E. I. ROUND WHITE POTATOES

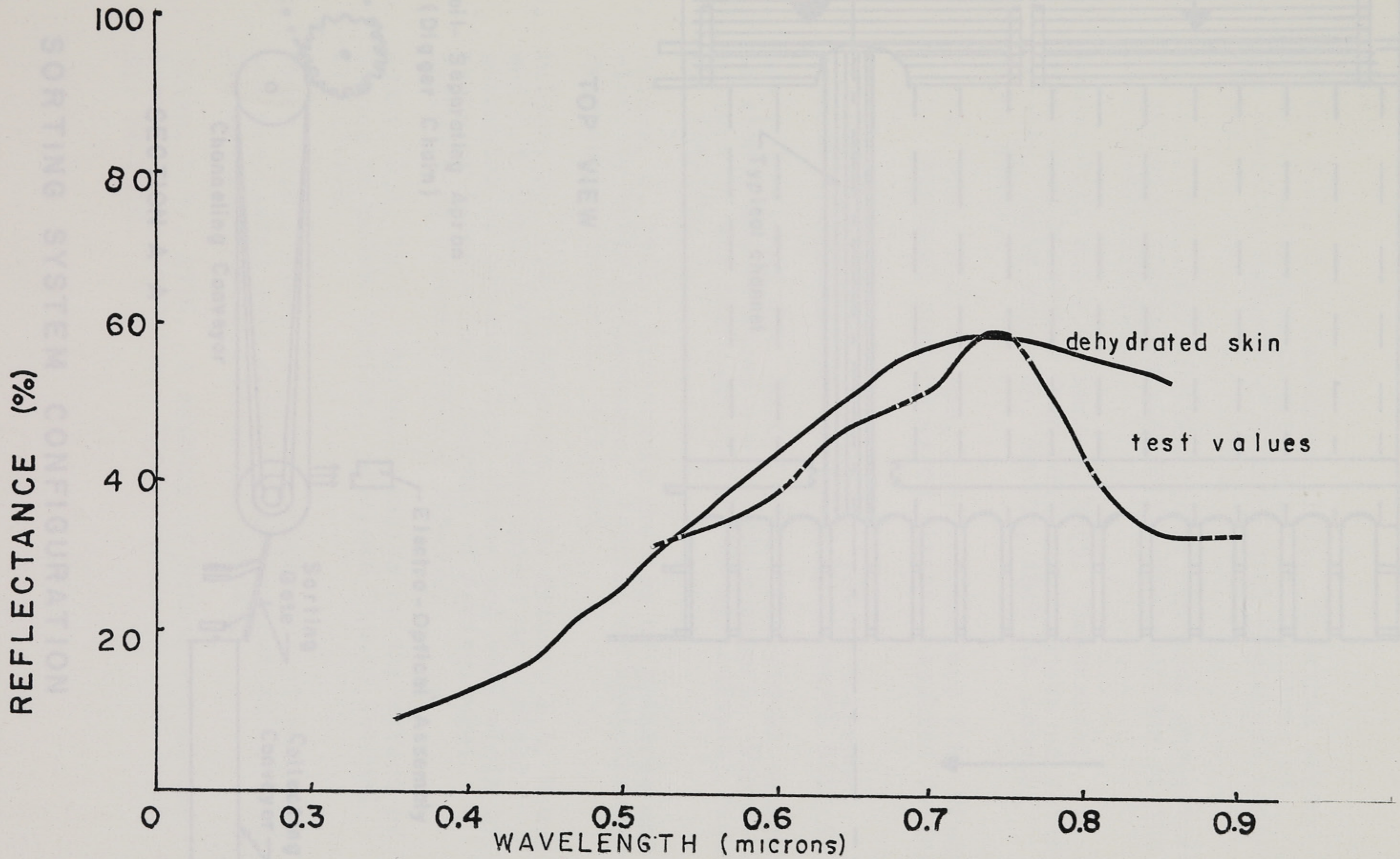


FIG 5 COMPARRISON OF TEST RESULTS TO DESIGN DATA

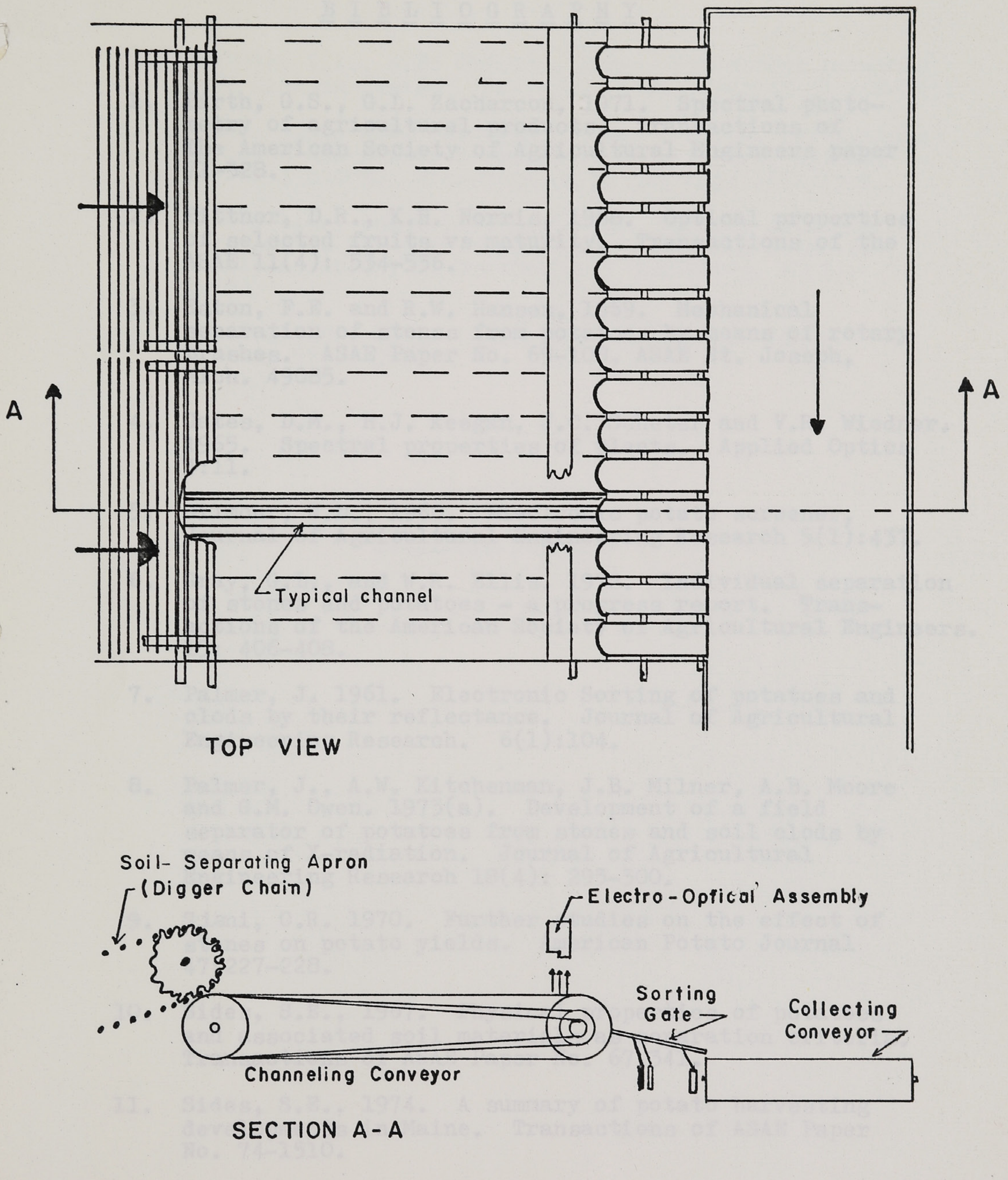


FIG 6 SORTING SYSTEM CONFIGURATION

BIBLIOGRAPHY

1. Birth, G.S., G.L. Zacharcon, 1971. Spectral photometry of agricultural products. Transactions of The American Society of Agricultural Engineers paper 71-328.

2. Bittner, D.R., K.H. Norris, 1968. Optical properties of selected fruits vs maturity. Transactions of the ASAE 11(4): 534-536.

3. Eaton, F.E. and R.W. Hansen, 1969. Mechanical separation of stones from potatoes by means of rotary brushes. ASAE Paper No. 69-108, ASAE St. Joseph, Mich. 49085.

4. Gates, D.M., H.J. Keegan, J.C. Scheter and V.R. Wiedner. 1965. Spectral properties of plants. Applied Optics 4:11.

5. Gilmour, W.D., 1960. Electronic potato screener, Journal of Agricultural Engineering Research 5(1):437.

6. Gray, G.L., and W.R. Ellis. 1972. Individual separation of stones and potatoes - a progress report. Transactions of the American Society of Agricultural Engineers. 15: 406-408.

7. Palmer, J. 1961. Electronic Sorting of potatoes and clods by their reflectance. Journal of Agricultural Engineering Research. 6(1):104.

8. Palmer, J., A.W. Kitchenman, J.B. Milner, A.B. Moore and G.M. Owen. 1973(a). Development of a field separator of potatoes from stones and soil clods by means of X-radiation. Journal of Agricultural Engineering Research 18(4): 293-300.

9. Saini, C.R. 1970. Further studies on the effect of stones on potato yields. American Potato Journal 47:227-228.

10. Sides, S.E., 1967. Physical properties of potatoes and associated soil materials as separation criteria. Transactions of ASAE Paper No. 67.341.

11. Sides, S.E., 1974. A summary of potato harvesting developments in Maine. Transactions of ASAE Paper No. 74-1510.

12. Smittle, D.A., R.E. Thorton, 1974. Harvesting potatoes with minimum damage. American Potato Journal 51:152-163.

13. Story, A.G., G.E. Holloway, 1973. Spectral reflectance of light and infrared radiation by potatoes, stones, and soil clods. Transactions of the ASAE 16(2):302.

14. Story, A.G., and G.S.V. Raghavan. Sorting potatoes from stones and soil clods by infrared reflectance. American Society of Agricultural Engineers. 16(2): 1973.

15. Witney, B.D., 1976. Stone free potatoes. Power Farming 56(3):35-37