THE USE OF SCRAP LEATHER

FOR ARTIFICIAL LEATHER SOLES

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Submitted in Partial Fulfillment of the

Requirements for the Degree of

Bachelor of Science

in

Chemical Engineering

from the

Massachusetts Institute of Technology

1943

Signature of Authors

Department of Chemical Engineering　　　　May 22, 1943

Signature of Professor in

Charge of Research

Signature of Head of the

Department

Massachusetts Institute
of Technology
Cambridge, Massachusetts
May 22, 1943

Professor George W. Swett
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Professor Swett:

In accordance with the requirements for the degree of Bachelor of Science, we herewith submit a thesis entitled The Use of Scrap Leather for Artificial Leather Soles.

Very truly yours,

Alfred B. Babcock, Jr.

William R. Kittredge.

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ACKNOWLEDGEMENT

The authors would like to express their gratitude to Professor Charles A. Stokes of the Department of Chemical Engineering for acting not only as a guide and sympathizer, but also as an invaluable source of information and advice.

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SUMMARY

The severity of the shortage of leather for civilian use due to war conditions has made it expedient for steps to be taken to solve this problem. A possible method counteracting the leather shortage lies in the utilization of approximately $76,000,000. worth of scrap leather which is unavoidably wasted every year. This scrap leather is at the present time being used for the production of heelboard, glue, fertilizer, etc., and in some cases is even being used as a fuel. Scrap is such an inconvenience to the tanneries that often it is given to those who will cart it away.

It was the purpose of this thesis to survey the literature and to determine in what ways scrap leather has been utilized in past years to produce artificial leather soles. A large number of patents were found which described processes and constituents which were used to make leather substitutes. A process for manufacturing artificial leather soles from leather scraps and polyvinyl acetate was outlined and a procedure was drawn up for investigating the feasibility of the suggested process.

It was found in the literature that, in general, four types of binders were employed to make artificial leather from leather scraps, with rubber being by far the most prominent. The others, proteins, resins, and miscellaneous binders, are, however, finding increasingly greater importance today because

of the current rubber shortage. In most cases, the plasticizers which were used were fatty acids, oils, and waxes, while the fillers were generally fibers other than leather or fine powders.

The processes suggested in the literature for the manufacture of artificial sole leather consisted of forming water-laid sheets of leather fibers and impregnating them by any of several methods with a binder and finally pressing and drying the sheets in calender rolls or a hydraulic press. There are indications that artificial soles made by these processes may have properties which compare favorably with those of natural sole leather.

It is possible that the suggested process may be severly limited by the freeness of the fibrous leather mass to which the resin binder has been added, since the nature of the process requires that this mass be filtered at a reasonably rapid rate. If this factor does not prove to be a limitation to the process, it is felt that a means of alleviating the present leather shortage and of utilizing leather waste may have been found.

INTRODUCTION

During the present war emergency, the demands upon leather of all sorts have increased to such an extent that it has been necessary to curtail the supply of leather used for non-essential or civilian purposes. Naturally, the shoe industry has been greatly affected by the decrease of supply and has tried to overcome this difficulty in several ways.

Some shoe manufacturers have produced women's play-shoes and slippers with soles made of coiled hemp rope, cork, cloth and other substitute materials. However, as these substitutes do not possess the qualities of leather, it would be most desirable to obtain a product whose properties closely approach those of natural leather, in tensile strength, resistance toabrasion and tearing, flexibility, and water repellency.

A possible solution to this urgent problem lies in the utilization of scrap leather. Each year approximately $76,000,000. worth of leather is unavoidably scrapped, this figure representing about 4% of the total yearly production. (1). As yet, a good and efficient means has not been found to utilize this scrap. Some manufacturers use their scrap as fuel, sell it for fertilizer, or even distill it for perfume, but all of these methods are wasteful of a potentially valuable material. If the leather scrap could, by some process, be converted to a product suitable as a sole leather, the shortage in non-essential industries could be greatly mitigated.

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(1) Estimate ofleather manufacturers.

In the past many ideas have been developed for processing scrap leather to form a leather substitute. Apparently many of these products have been unsatisfactory in some respects, or have required a process which is too impractical since the products have not yet found widespread use by the shoe manufacturers.

A literature survey was made of these and similar products which have been made or developed since 1907. Books did not yield any useful information, as most references concerning the utilization of scrap leather dealt with its distillation for by-products, or use as a fuel or fertilizer. By far the most valuable sources of information were the abstracts of patents and chemical periodicals. The patents were more useful than the periodicals since their abstracts gave more definite and detailed information. The original patents were not consulted since it was felt that the abstracts gave a sufficient indication of the worth of the process. Any periodicals which appeared to be of value were unavailable in the local libraries.

All the products made as a leather substitute, which utilized scrap leather fibers or in some cases leather powder, used binders or agglutinating agents, which generally were, (1) rubber, (2) proteins, or a few miscellaneous binders, or (3) resins. A few processes did not use any binder at all, but simply relied upon the interlocking of the fibers, alone or incorporated with other long fibers, for strength. A binder must not only make the product strong, but also must impart to it flexibility and resistance to abrasive wear. If the substitute will be in contact with water at any time, it must also be water repellent so that the tensile strength of the material will not be impaired by the separation of the fibers or their lubrication.

The binder most often used in conjunction with leather waste was rubber latex. Generally two separate methods were used to make the product, that in which the product was vulcanized, and that which just heated and pressed the mixture of rubber and leather fibers into sheets. In the cases where vulcanization was employed, vulcanizers and accelerators were added to the latex-leather mixture. The vulcanizers were sulfur and zinc oxide, and the accelerators were generally aliphatic hydroaromatic or aliphatic heterocyclic amines.

Often plasticizers are needed in the manufacture of leather substitutes in order to render the product more flexible, although excess of plasticizer will markedly decrease tensile strength. If no plasticizer were used, a stiff binder would lie in between the fibers and it would be expected that the flexibility of the product would be low. In the case of rubber-leather products, plasticizers of vegetable or mineral oils were usually used when an auxiliary resin binder, either natural or synthetic, was employed.

In many cases a filler was used with rubber-leather products to increase their resistance to abrasion and their tensile strength. At the same time, however, fillers decrease flexibility, so that a compromise must be reached in the proportion used, if a product suitable as a leather substitute is desired, Some of the substitutes utilized other vegetable or mineral fibers as an aid to the leather fibers. These fibers are usually longer than the leather fibers and help to form a stronger mat.

The second type of binder which was employed by the earlier investigators was a protein such as glue, casein, or albumin. They were sometimes used with auxiliary binders, such as phenolic resins or drying oils. Glycerol was almost always employed in connection with glue. Cotton or cellulose fibers in some cases were added for extra strength, while infusorial earth, graphite, mica, or red lead were used as fillers.

Thirdly, resins were quite common as a binder of leather scraps, and included varnishes, phenol-aldehydes, polyvinyl esters, cellulose esters, glyptals, and amino-aldehydes. Occasionally a filler such as sulfite pulp was used. Plasticizers were not used very frequently in those products described in the literature, although dibutyl phthalate was used in conjunction with polyvinyl acetate as described in the thesis of B. Brindis.*

Miscellaneous binders include drying oils, tars, asphalts, lignin, etc. These substitutes used the usual fillers and auxiliary fibers, but utilized paraffin and crude petroleum waxes as plasticizers.

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*B. Brindis, Utilization of Scrap Leather as a Substitute for Sole Leather. M.I.T. B.S, Thesis in Chem. Eng., Jan. 15, 1943.

Because many of the constituents aforementioned are unavailable during wartime, the processes which embody them are impractical during this emergency. In the light of existing shortages of certain raw materials and machinery, a process which avoids these shortages has been proposed.

Either vegetable or chrome-tanned leather scraps are cut up into pieces of about one-half inch in size. These chips are then put into a beater of the hollander type which is used in the paper industry, water is added to make a mixture of about 15 per cent solids, and the mixture is beaten for several hours. The actual time of beating would vary from batch to batch, but will be considered sufficient when the leather has been broken down to a mass of loose fibers, similar to a wood pulp slurry. The time required for this would be determined only by experiment. When the leather has been beaten sufficiently, the slurry is removed from the beater and filtered in the same fashion in which wood pulp is filtered, in order to remove the nibs or other particles which did not break up into fibres. At the same time the mass is washed well so as to remove all traces of the tannin which was once contained in the leather. After washing, the leather slurry would be returned to a beater, and, if desired, a certain quantity of wood pulp could be added to the slurry. It is felt that the long fibers of the wood pulp might serve as a binder for the short leather fibers and also increase the tensile strength of the whole mass since the wood fibers are probably stronger than the leather fibers.

The two types of fibers are mixed for a short time in the beater, and then a resin binder is added. There are a number of resins which might be used, but to name them all would be impossible. The resin which is recommended in this process is polyvinyl acetate, which has already been used with some success by previous investigators.* This resin is employed in emulsified form, 53 per cent of polyvinyl acetate in water being the emulsion which was found most suitable. The resin emulsion has been found to break almost immediately upon contact with the leather fibers**, depositing the resin upon the fibers where it may act as a binder. It is felt that the final sheet will be far more flexible if a plasticizer is also added to the leather-pulp-resin mixture. The suggested method for adding the plasticizer is to add it to the resin emulsion before the latter is added to the fibers. It is believed that the plasticizer will have no effect upon the emulsion, but that a plasticized resin will still deposit upon the fibers. After addition of the resin and plasticizer, the mass is beaten again to thoroughly disperse the resin.

With the resin deposited upon the fibers, there are several ways in which the final sheets of artificial leather may be formed. First of all, sheets might be turned out on a wet wheel such as is used in the pulp industry to make wet lap.

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* B. Brindis, ibid

** Ibid

The wet wheel would remove enough water so that the leather mass would stick together with sufficient strength so that it could be drawn through a drying tunnel, countercurrent to a stream of hot dry air, which would evaporate the remaining water. As the sheet left the tunnel it would be led through a pair of calender rolls where the sheet would be compressed to increase the density and to increase the binding power of the resin.

Another method by which the resin-coated fibers which leave the beater might be treated is to feed them to a Fourdrinier or dry lap machine similar to that used in the paper industry. Since the resinous leather mass will undoubtedly be less free than the paper pulp which is ordinarily fed to such a machine, thinner sheets will have to be formed to give the water a better chance to leave the fibers. However, these thin sheets might be placed upon one another and either pressed or led through calender rolls to unite them into one sheet of greater thickness. The resulting sheet or the sheet resulting from the process mentioned earlier would then be cut into pieces a few feet square and placed in a heated press and several thousand pounds pressure applied. Since the resin is thermoplastic, this treatment would soften it temporarily so that it could further penetrate between and adhere to the fibers. After this the artificial leather would be ready for special treatment such as embossing, dyeing, etc.

It has been suggested that the final product might possibly have a low tear resistance, which would mean that when the sole is stitched to the rest of a shoe, the threads might possibly pull through the sole. In the event that the product should turn out to have such a property, it might be remedied by the insertion of sheets of fabric between the layers of leather before they are pressed or calendered.

As can be seen, it is the purpose of this method of artificial leather manufacture to make use of as much as possible of the equipment which would be available in a paper or pulp mill. By so doing, the cost of both plant and machinery could be greatly reduced, and the task of finding new machinery overcome. Furthermore, there are indications that in the near future polyvinyl acetate will become available in quantities sufficient for the commercial production of this artificial leather.

Therefore, it is the purpose of this thesis to make a survey of the literature in order to determine what processes if any are similar to the one outlined above, to determine what materials and processes have been used with success in the past, in the hope that some of them might be applicable and an aid to the process planned for the present, and to suggest a laboratory procedure by which the feasibility of this process might be tested by future investigators.

PROCEDURE

Since it was not the purpose of this thesis to carry out any experimental laboratory work, it is not possible to describe the procedure followed by the authors. However, in the light of the suggested process, it is possible to outline the procedure which would have been followed, in the hope that such an outline will be of assistance to future investigators.

Rather than attempt to design a beater in which to digest the leather scraps, it is felt that leather heelboard, broken up in water, will furnish a slurry of leather fibers which will correspond to a product of several hours beating. Leather heelboard is simply a cardboard-like substance which results from pressing and drying a mat of beaten leather fibers. This board breaks up rapidly in water and reforms a fiber slurry.

Investigation of the washing and filtering qualities of this slurry would probably not be carried out, since the laboratory slurry would certainly not have a tannin content similar to that which might be encountered industrially, and since the construction of nib-removing filters would hardly indicate whether such a removal would be possible on the type of filter used in a pulp mill. However, in the laboratory investigation, the leather slurry should be washed and any nibs or large impurities should be removed by filtration. Runs might also be made without removing nibs and impurities to determine whether their removal affects the product in any way.

The prepared leather slurry would then be ready for the addition of wood pulp, if desired, and of the binder and plasticizer. This stage of the process is a critical one, for there are a great many variables whose effects upon the process or product must be determined. It might not be out of place to list the more important of these variables, so that in the investigation they might either be kept constant, or so that runs may be made to note their effect.

1. Concentration of leather slurry.
2. Concentration of wood pulp in slurry.
3. Length of fibers of wood pulp.
4. Concentration of resin in slurry.
5. Concentration of resin in emulsion.
6. Ratio of plasticizer to resin.
7. Type of plasticizer.
8. Temperature of slurry.
9. Length of stirring time after resin addition.
10. Whether resin and plasticizer should be mixed before or after addition.

There are undoubtedly other variables than those mentioned above, whose effect might also be noted, but it is plain that with only those listed there must be considerable work done to determine the optimum values of these variables.

It is felt that the wood pulp should be added before the resin in order that it too may be coated with the resin and make the final product stronger. The pulp might be obtained by breaking up paper or blotter in water, and washing to remove any sizing which might be present. It cannot be said whether the fibers obtained by this means would be too short, but this would have to be determined by experiment. Having mixed the leather and wood fibers well, the resin and plasticizer would then be added. As mentioned in the suggested process, these two could probably be blended together before adding them to the fibers.

By limiting the resin to polyvinyl acetate the number of plasticizers which may be used is also limited. It is often true that one plasticizer will be better than all others for a certain resin. A literature survey might very well discover the most suitable plasticizer for this resin, so that the one of the important variables can be placed at or near its optimum value without any trial-and-error runs.

After the addition of the resin and the plasticizer, the slurry should again be stirred until the resin is deposited homogeneously throughout the mass of fibers. As has already been pointed out, this time of stirring will have to be determined experimentally. The freeness of the mass at this point is of utmost importance since the success of the process depends upon the ability of the mass to filter properly on paper machines. Consequently the freeness should be measured, and compared with that of the paper pulp made on the machines. The standard freeness test used in the paper industry should be adequate. After the resin has been completely dispersed, the leather mass would then be placed in some sort of filter and the water removed by either a vacuum applied below the mass or by a pressure applied above it. It is doubtful, considering the poor freeness which the mass might have, that the vacuum below will be sufficient to dry the mass in a short time. Consequently pressure filtration will probably be found necessary. A quantity of the leather mass sufficient to make a mat of approximately shoe sole thickness should be placed upon the filter. In later runs it might be desirable to make thinner sheets, not only to test their properties, but to investigate the feasibility of making a sole by the lamination of several thin sheets of the artificial leather.

The sheet which is formed by the filtration process would be put under a considerable pressure in a hydraulic press and heated simultaneously. This would tend to complete the drying of the sheet, and would affect it in a manner similar to that in which the calender rolls would affect the sheet in the proposed industrial process. The temprature and pressure at which the sheet should be treated will have to be determined by trial-and-error, and the possibility of the resin being thermoplastic should not be overlooked.

The final product is then ready for testing. The requirements of a good sole leather are that it be flexible, abrasion-resistant, tear-resistant, and water-resistant. A comparison of the properties of the artificial sheet with those of a sheet of good sole leather would be advisable. A possible test of flexibility would be to bend two samples the same amount and note in which sample cracks appear first. This is not too rigorous a test, and where two samples appear to have the same flexibility, it might be wise to place them in a machine which would flex them continually over a long period of time. Differences in flexibility which did not show up before might appear after such treatment. As an abrasion tester, the machine described in the B.S. thesis of B. Brindis*, would probably do very well, and it had quite a high degree of accuracy. The tear-resistance of the sole is of no minor importance since the threads joining the sole to the rest of the shoe will pull through the sole unless it has sufficient resistance to tear. A machine to test the tear resistance of a piece of leather might be built along the same lines as the machines which are used to test the tear resistance of paper. A water resistance test might consist of weighing a sample of leather before and after immersion in water for definite period of time. The gain in weight per unit weight of sample would indicate the willingness of the sample to absorb water. Other tests could and should certainly be devised where these tests fail to indicate the true properties of a sample.

In regard to increasing the tear-resistance of the artificial leather, it has already been proposed that thin sheets separated by some sort of fabric which were laminated by pressure and heat might possibly have greater heat-resistance than a single thick sheet of the product. Such a possibility should certainly be investigated, for the laminated

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*B. Brindis, Ibid.

sheet might very well be better than the single one in many respects other than tear-resistance, particularly flexibility.

Although it would be desirable to test the fiber mass just after the resin has been added and mixed, the form of the mass at that time seems to make tests out of the question. The only really suitable opportunity for physical tests on the artificial leather is after the sheet has been formed, and since there are a large number of variables to be investigated, a large number of sheets must be made and tested. Consequently, if a thorough job is to be done on this problem of artifical leather, it must be expected that a considerable amount of time will have to be expended in the laboratory.

RESULTS

1. The constituents which have been used in the past with scrap leather to form an artificial sole leather are presented in tabular form on Page 19.
2. The more important and promising methods of producing artificial leather which have been employed in the past are listed below:
   a. A fiber sheet is impregnated, pressed, and vulcanized, (if rubber is the binder).
   b. A fiber sheet is brought in contact with a roller which is coated with the binding constituents.
   c. A thin fiber sheet is impregnated by spraying on the binder, after which several such sheets are pressed together.
   d. Detanned fibers are mixed with binder to make a paste which is dried and compressed.
   e. A water-laid fiber sheet is impregnated by passing through a bath containing the binder.
   f. Fiber fleece is treated with adhesive so that the binder will stick, then impregnated in a number of steps by passing through low pressure cylinders which are coated with binder, and calendering after each step.

g. Fiber is beaten in water, dried and suspended in benzene, binder (rubber) is added which precipitates upon the fibers.

h. A mixture containing rubberized fabric is churned until aerated enough to make fibers rise to top, then filtered and pressed.

i. Fibers are deposited from an air suspension, are compressed and then impregnated with binder.

j. Fibers are blown onto a suction screen along with a rubber suspension.

k. Comminuted waste leather is worked into a sheet on a paper-making machine.

l. Comminuted leather is added to a rag - NaOH mixture. Tanning agent precipitates the dissolved leather upon the rag fibers, and the product is worked up on a paper-making machine.

m. Fibers deposited by air onto a conveyor belt, which carries them through an impregnating bath.

3. The procedure to be followed in testing the suggested process has already been presented in the PROCEDURE.

CONSTITUENTS COMBINED WITH LEATHER SCRAP TO FORM ARTIFICIAL LEATHER

TYPE OF BINDER

	RUBBER	PROTEINS	RESINS	MISC.
Binders	latex sol. artificial rubber	glue casein albumin	phenol-aldehydes cellulose esters amino-aldehydes polyvinyl esters glyptals varnishes	asphalt, tar lignin japan wax linseed oil
Plasti-cizers	oleic acid mineral oil olive oil	paraffin wax castor oil glycerol	dibutyl phthalate	stearic acid paraffin wax petroleum wax
Fillers	fabric asbestos wood pulp carbon, tar resins, glue	phenolic resins infusorial earth mica, red lead cotton wood pulp	sulfite pulp	cotton fiber clay paste
Accelerators	aliphatic hydroaromatic amines, etc. alcohols			
Vulcan-izers	sulfur zinc oxide			

DISCUSSION OF RESULTS

Constituents.

During the present emergency there has been a shortage of raw materials, so that many of the constituents referred to in the literature are unavailable for the production of artificial leather. The most outstanding example of this difficulty is rubber. The majority of the leather substitutes invented have used rubber as a binder because of its strength, flexibility, and water resistance. However, natural rubber or even the new artificial rubbers would not be obtainable for non-essential uses, and would eliminate the possibility of making artificial soles of scrap leather and rubber.

Another binder which was used quite frequently was glue, probably because of its adhesive qualities, availability, and cheapness. A plasticizer should be used in conjunction with glue, however, in order to produce a material which is flexible. Waxes, oils, and glycerol were most often used as plasticizers although they are probably by no means the only ones which might be employed advantageously. Brindis* worked with glue and castor oil, but found the results to be unsatisfactory from the flexibility standpoint. However, it is still felt that glue with scrap leather might make a product which would be satisfactory in certain limited cases such as heelboard, although the product might not be

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* B. Brindis, Ibid.

sufficiently waterproof.

The miscellaneous binders such as tar, asphalt, linseed oil, or lignin were mentioned infrequently in the literature which indicates that either they were unsatisfactory in their application or that they have not been investigated to any great extent. Linseed oil was mentioned more in connection with other binders than as a solitary binder for leather waste. This drying oil would not be as available, however, as the other binders in this class. Lignin is a waste product of the paper industry and its utilization along with waste leather would be doubly economical, providing, of course, that the product is suitable as a leather substitute.

Resinous binders such as those mentioned in the table of the RESULTS are generally fairly difficult to procure for non-essential industries during wartime. There is reason to believe, however, that vinyl resins which are being produced in increasingly greater quantities will become available to the less essential users.

While in the recommended process only one resin was mentioned, namely, polyvinyl acetate, it should not be inferred that the process would be worthless if some other resin were used in its place. Certainly, if polyvinyl acetate becomes unavailable, or if some other resin is found to possess better properties and is less expensive, the acetate will be discarded. However, at present, polyvinyl acetate is the only resin for which there has been found data to prove that it is adaptable to the process. Until similar data is found for other resins, the process must therefore be limited to the use of polyvinyl acetate.

No reference was made in the literature to plasticizers which were used with resins, although in most cases it seems imperative to use one or more of them. Dibutyl phthalate was used by Brindis* with success in his work with polyvinyl acetate, although there is no reason why this should be the best plasticizer.

The fillers used in the products were of two types, powdered and fibrous. Powdered fillers fill up voids and make the product more resistant to abrasion and increase its tensile strength, but also increase its stiffness. The fibrous fillers were usually vegetable, animal, or mineral fibers (asbestos). Vegetable fibers, in general, would be longer than mineral fibers and would therefore tend to produce a more cohesive mat.

Processes.

In the processes listed in the RESULTS, the preparation of the fiber sheets which are to be impregnated, is not mentioned. The reasons for this are twofold. First, the patents did not always include this details, and secondly, such a sheet was usually only a mat formed by filtering the water from an aqueous leather suspension. As can be seen such a sheet is necessary if a flow process for the production of artificial leather is desired.

The differences between the various artificial leather processes cited in the RESULTS seem to be mainly in the method of impregnation of the leather sheets. Of the possible methods of impregnation, the four general types which appear to be the most feasible at this time were the roller, the spray, the bath, and the batch mix methods. All of these but the latter require that the binder and other constituents to be added to the leather be either soluble or suspendable in a liquid. This would also be desirable in the batch mix method, but is not essential. It is difficult to comment upon the advantages of the different types of impregnation, since no data is available on the physical properties of their products. However, from the nature of the methods, one would believe that the roller and batch methods of impregnation would be more successful in producing a homogeneous leather mixture. The other two methods appear to be more suitable for merely coating the fiber sheet.

Following the impregnation of the sheet, the procedure was nearly the same for all artificial processes in that pressure was applied, either by calender rolls, or by a hydraulic press. Whichever is used, the effect on the product is the same. It is interesting to note the number of methods which were listed in which the machinery of a paper mill could be employed. Also of interest are the two methods which specifically called for paper-making machines. Evidently the idea of using paper-making machinery for producing artificial leather is neither new nor unexploited.

Several of the early methods of preparing artificial leather specified treatment of the leather fibers with solutions before impregnation. Had there been any agreement amongst the methods as to the type and necessity of these solutions, they would have been mentioned in the RESULTS. When used, the purpose of these solutions was to detan the leather scraps or to swell the fibers so that the impregnation with the binder would be facilitated. Since previous investigators were not in agreement as to the advisability of or the type of such solutions, their use was omitted from the suggested process.

Limitations of the Process and Product.

If there were any unsurmountable limitations in the process of producing a substitute from scrap, it obviously would not be advisable to expand it to an industrial scale. The principal limitation which comes to mind is the cost of manufacture. The binder and plasticizer would be the most important single item, the cost of manufacture probably mounting to about 90% of the cost of these materials. However, until the optimum ratio of leather to resin can be determined, it cannot be said whether or not this process is economically feasible.

A second limitation is the availability of machinery during the present emergency. Paper machines such as the hollanders and lap machines have been suggested for use because they have been designed for a similar material. If because the demand upon these machines from the paper industry is too heavy, it will be necessary to use similar, available machinery, if any, of other industries, or to design and build new ones. If equipment must be made, much can be made of wood or ceramics, although equipment such as motors, pumps, presses, and machine parts must be purchased and will naturally be difficult to obtain.

The freeness of the mass just before filtering is of utmost importance. The suggested process make use of the machinery of the paper industry, either the wet lap or Fourdrinier paper machine. These machines require that water be removed continuously from the mass by a vacuum through a screen or felt. It may be that the freeness of the composite mass is so low that water is not removed at a sufficient rate to merit the use of the continuous machines as much, and therefore a thorough investigation of the freeness is essential to the success of the process. Redesign of the machines may be expedient in order to permit a greater driving force to overcome a poor freeness. The machines as they are now designed can only produce about a 28 inch vacuum. If in some way pressure could be applied above the slurry while filtering, there would be almost no limit to the driving force obtainable.

The finished product would probably not have properties similar to those of the natural leather and it would therefore be limited to uses where the lack of these properties was inconsequential. While this paper is principally interested in a substitute suitable for sole leather, it might be advisable to note in what respects its use in other applications would be limited.

It is very likely that the substitute made from the scrap and resin such as polyvinyl acetate would not have the "breathing" quality of natural leather, or in other words, the ability to pass vapor at a fast rate. This would prevent the use of this substitute as shoe tops.

Because the fibers are bound together by a resin which exhibits permanent set under moderate tensile stresses, it is reasonable to believe that the leather substitute will act in a similar manner, in which case the product would not be recommended for use as a belt leather which must maintain its elasticity under load. It might be said that because of the permanent set the substitute might not be useful as a sole leather. However, the tensile stresses which shoe soles undergo are probably small enough to make the set of little importance.

The artificial leather might also have advantages over natural leather. The substitute is likely to be more water-resistant than natural leather because of the presence of a water-repellent resinous binder. This property would make the product even more suitable for shoe soles.

One might be led to believe that if substitute leather were comparable in every way to natural leather, and was cheaper it might lead to the replacement of the latter in shoe soles. It must be remembered, however, that the scrap is only a relatively small percentage of the leather industry's total production, so that as long as artificial leather soles contain a large per cent of scrap leather, than can never replace much more than about 5% of the Country's natural leather.

RECOMMENDATION

Since it was one of the purposes of this thesis to suggest a laboratory procedure for investigating the feasibility of manufacturing artificial leather soles from scrap leather, it is recommended that if such an investigation be carried out, the procedure outlined in this thesis be given due consideration by the investigators.