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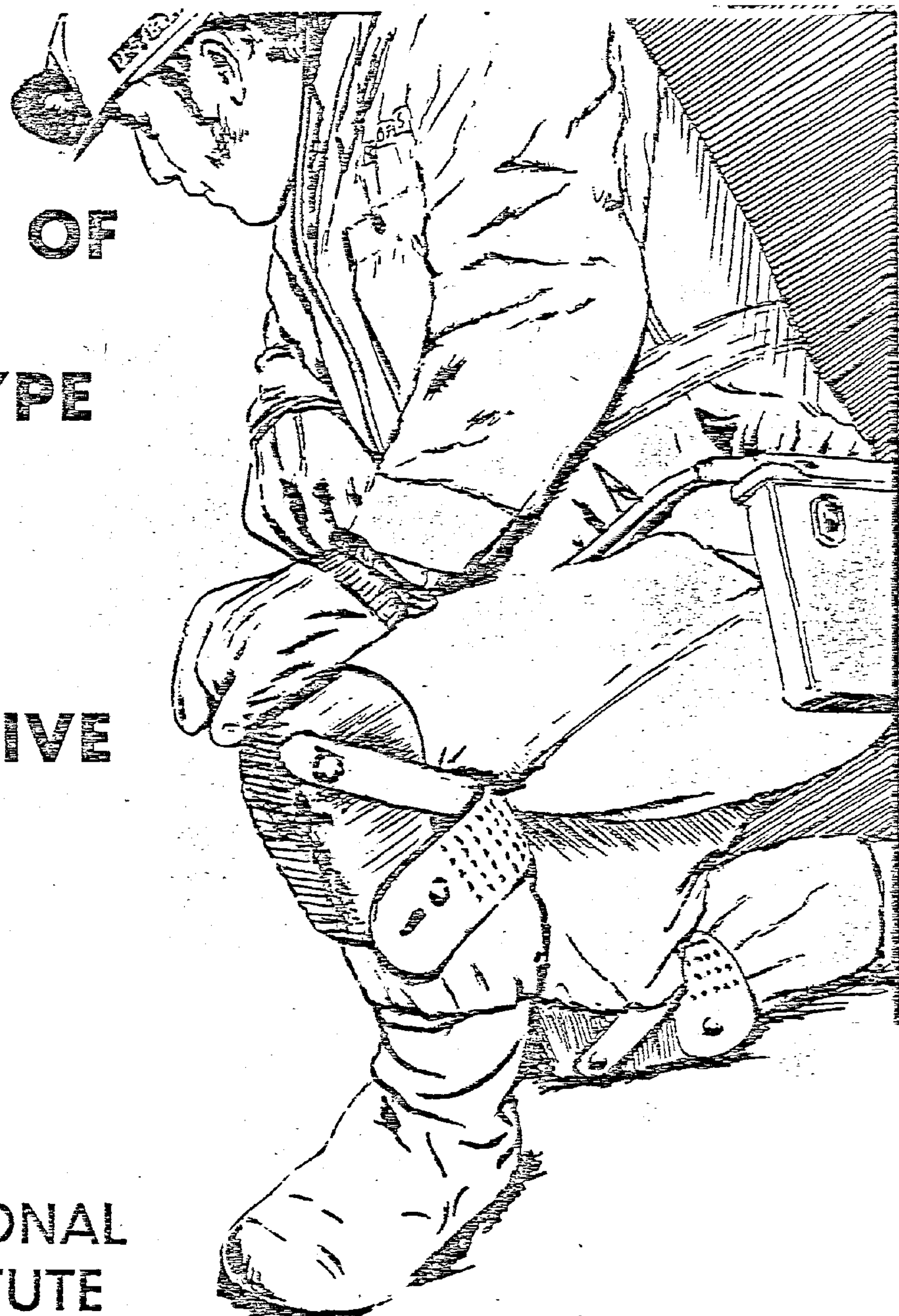

TESTING OF PROTOTYPE KNEE-PROTECTIVE DEVICES

FOR: NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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Thal-Larsen, E.P. and Sleight, R.B.

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Ever since man started working in "low coal" mines with ceiling heights requiring crawling, pre-patellar bursitis or "miner's knee" has been a leading cause of temporary and also permanent disability among miners. In an earlier project, Century Research Corp. defined the basic configuration of a knee pad specifically designed to prevent pre-patellar bursitis in the wearer. The purpose of the present study was to develop this prototype into a knee pad that would find a high degree of acceptance among coal mine workers.

The result of the study is a knee pad design which rated second out of nine in the comparative evaluation. Also, the study outcomes were several recommended minor design modifications; recommendations for suitable production materials and methods; and larger range recommendations based on accumulated low coal mine experience regarding future miner's clothing and personal work, health, and safety equipment.

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ABSTRACT

A recently developed experimental prototype for a new knee pad was tested under actual low coal mine conditions.

This knee pad was especially designed with the objective to reduce pre-patellar bursitis. After the evaluation, carried out by U. S. Bureau of Mines inspectors, the design was modified on the basis of the inspectors' comments, which were recorded on prepared forms. This procedure was repeated three times, each time leading to new modifications. The last evaluation was a comparative one, comparing the performance of the experimental pads to that of eight other, commercially available ones. The experimental pad was judged No. 2 in the overall comparison.

HSM 99-72-81

TESTING OF PROTOTYPE KNEE PROTECTIVE DEVICES

FINAL REPORT

For

Division of Criteria and
Standards Development
National Institute for Occupational
Safety and Health
1014 Broadway
Cincinnati, Ohio 45202

By

Ernst P. Thal-Larsen and Robert B. Sleight
Century Research Corporation
4113 Lee Highway
Arlington, Virginia 22207

March 1974

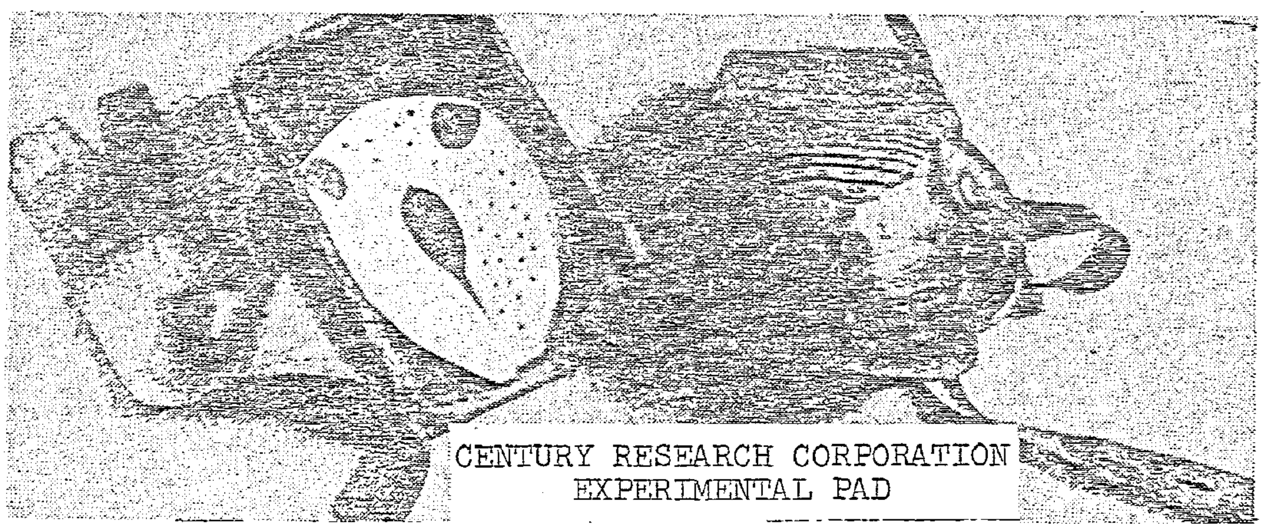
TESTING OF PROTOTYPE KNEE-PROTECTIVE DEVICES*: SUMMARY

REASON FOR STUDY. Ever since man started working in "low coal" mines with ceiling heights requiring crawling, pre-patellar bursitis or "miner's knee" has been a leading cause of temporary and also permanent disability among miners. In an earlier project, Century Research Corporation defined the basic configuration of a knee pad specifically designed to prevent pre-patellar bursitis in the wearer. The purpose of the present study was to develop this prototype into a knee pad that would find a high degree of acceptance among coal mine workers.

METHOD. The method by which this development took place was a field test/prototype modification cycle. A number of the knee pads were fabricated according to existing design specifications. They were then worn in low coal mines by a number of U. S. Bureau of Mines inspectors who volunteered for the testing phase of the project. Their findings, comments, and recommendations were recorded on prepared forms, which were then analyzed to provide guidelines for design modifications. A number of knee pads of the modified design were then prepared, and again tested in the same manner.

This cycle was repeated three times, and the last test phase was used as a comparative evaluation, where the experimental pads of the latest design were rated on a numerical scale, in comparison with all the locally commercially available pads, plus some locally unknown imports.

FINDINGS. The result of the study is a knee pad design which rated second out of nine in the comparative evaluation. Also, the study outcomes were several recommended minor design modifications; recommendations for suitable production materials and methods; and larger range recommendations based on accumulated low coal mine experience regarding future miner's clothing and personal work, health, and safety equipment.



CENTURY RESEARCH CORPORATION
EXPERIMENTAL PAD

*Thal-Larsen, E. P. and Sleight, R. B. CENTURY RESEARCH CORPORATION. A study for the National Institute for Occupational Safety and Health, March 1974.

Century Research Corporation experimental knee pad being worn during in-mine evaluation.

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ACKNOWLEDGEMENTS

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We also want to express our thanks to Dr. Clifford A. Stevenson of the Southern West Virginia Clinic in Beckley for his valuable orthopaedic advice.

Finally, we wish to express our appreciation to the two project officers, Francis J. LaPallo and Richard J. Lewis, who each in turn have lent patient guidance and support to this effort.

Ernst P. Thal-Larsen

Robert B. Sleight

TESTING OF PROTOTYPE

KNEE PROTECTIVE DEVICES

INTRODUCTION

In a report entitled "Improved Knee Protective Devices for Mine Workers," published in January 1972, Century Research Corporation stated the need for the development of a knee protective device capable of significantly reducing the incidence of pre-patellar bursitis among low coal mine workers. The report goes on to describe an experimental knee pad designed specifically with this objective in mind.

Although the first prototype has since then undergone many design changes, some of them radical, two basic features were retained throughout the development: a tough, semirigid outer shell, and a soft, removable inner cushion with a relatively high profile and shaped somewhat like a horseshoe. These features were the result of numerous interviews with knee pad users, mine workers as well as Federal and state mine inspectors; of consultations with an orthopaedic surgeon with extensive "miner's knee" experience, a physician, and several orthopaedic technicians.

This report deals with the purpose, the method, results and conclusion of a subsequent, related contract, in which later configurations of the experimental knee pad were evaluated in a low coal environment by volunteers from the U. S. Bureau of Mines 4th District office of Mount Hope, West Virginia. (A "low coal environment" is a mine where ceiling height requires crawling.) A number of these evaluations took place, in which the volunteers would record their experiences with the knee pads on prepared forms. After a given number of these forms had been filled out, the results would be analyzed and reduced to a number of recommendations for design changes, which would then be incorporated into the next prototype.

This cycle was repeated three times, during which some radically different configurations were evaluated. The semirigid outer shell and the horseshoe-shaped inner cushion were basic to each configuration, however. The theory throughout the evaluation has been that this particular inner cushion design would significantly reduce the incidence of pre-patellar bursitis by alleviating the pressure concentration under the patella. The relatively high profile of the cushion in turn led to the concept of the semirigid outer shell, designed to maintain stability. The design changes described in this report were all necessitated by factors other than the incidence or non-incidence of pre-patellar bursitis. These factors were:

comfort,
control (position retention), and
convenience (ease of donning and doffing, lack of bulk).

Most of these factors had direct bearing on one another, and occasionally trade-offs had to be made. The last configuration described in this report is the end-result of this gradual debugging process, embodying trade-offs of all the features deemed desirable by the volunteers who tested the earlier prototypes.

Whether or not it will significantly reduce the incidence of pre-patellar bursitis is a question which can only be answered by continued and larger scale testing of this knee pad.

The last evaluation described in the "Method" chapter of this report is a comparative one, attempting to establish a more or less objectively structured scale of preference among nine volunteer U. S. Bureau of Mines inspectors for eight commonly used knee pads (U. S. and foreign-made) and the Century Research Corporation designed experimental pads.

In Figure 1 we have a dramatic illustration of the swelling which is a main feature of pre-patellar bursitis (also called "miner's knee").

PURPOSE

This evaluation program was conducted to obtain information leading to the further development of a knee pad specifically conceived to reduce the incidence of pre-patellar bursitis among low coal mine workers.

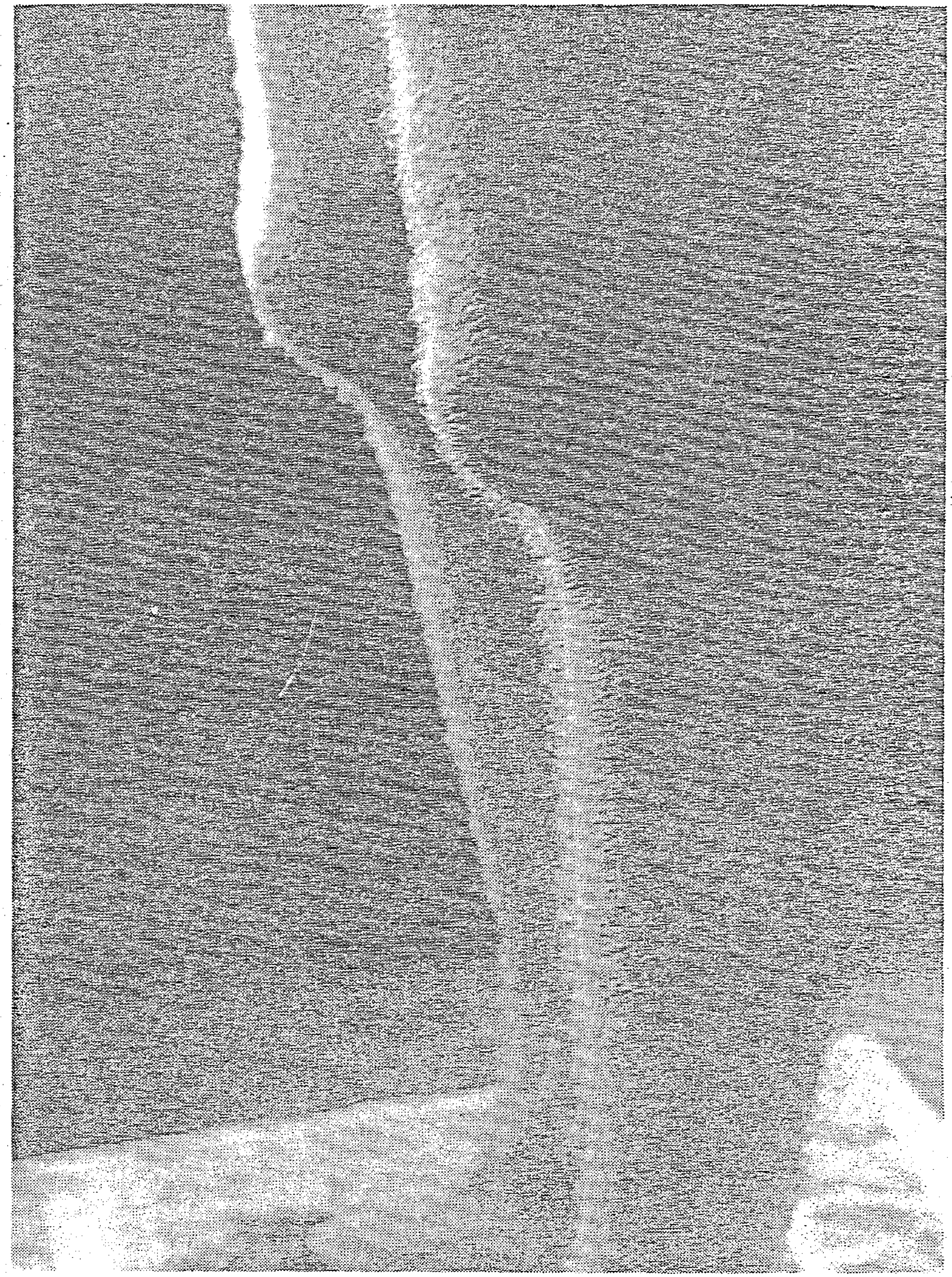

Figure 1. The knees of a miner with pre-patellar bursitis. In severe cases of this affliction the swelling is such that the patient is incapacitated and the bursa has to be surgically removed.

METHOD

It is probably more correct to refer to the method used in this contract as "prototype development and field testing," since what took place was a cycle of design, fabrication, field testing, redesign, alteration, field testing, etc. In order to report the process comprehensively, a short description of the initial prototype and the principles it was based on is necessary.

The Initial Prototype

The first experimental knee pads were designed from specifications which were drawn up after a thorough investigation of the subject, which included interviews with dozens of low coal mine workers, Federal and state mine inspectors, consultations with an orthopaedic surgeon in a low-coal mining region, with a physician, and with several orthopaedic technicians, as well as a review of all the patents issued on knee pads over the last hundred years.

The result was a knee pad that consisted of a low, barge-shaped outer shell made of a tough, semirigid rubberlike material, with deep, V-shaped treads on the bottom; a thick (1 3/4" dia.) cylindrical cushion bent into a horseshoe shape, made of fine pore, open cell polyurethane foam with a smooth, tough skin; and a wide, curved rubber strap, perforated for ventilation, and fastened to the knee pad by means of rubber mushroom-shaped buttons. (See Figures 2, 3, 4) The objective of the unusually shaped inner cushion was to relieve the pressure normally concentrated on the tibiar tubercle when a person kneels or crawls. This pressure is held to be largely responsible for causing pre-patellar bursitis. On the new cushion, the wearer's weight was distributed over a relatively large area on either side of the patella, and to some extent, across it.

Since the cushion was quite thick compared to existing knee pads, a method had to be found to keep the pad stable, i.e. to prevent it from "rolling under," a complaint that had often been heard against a commercially available pad with a relatively thick cushion. This led to the wide, flat-bottomed outer shell with rather rigid sides and bottom. (See Figure 5)

The wide, curved strap was intended to hold the pad in place on the wearer's leg without making contact with the hamstring. This required somewhat more pressure on the calf than with the usual two-strap system, and in order to distribute this pressure evenly the strap was made wider than usual. The strap fastened to the pad with three rubber buttons, forward center and back on one side of the pad's outer shell,

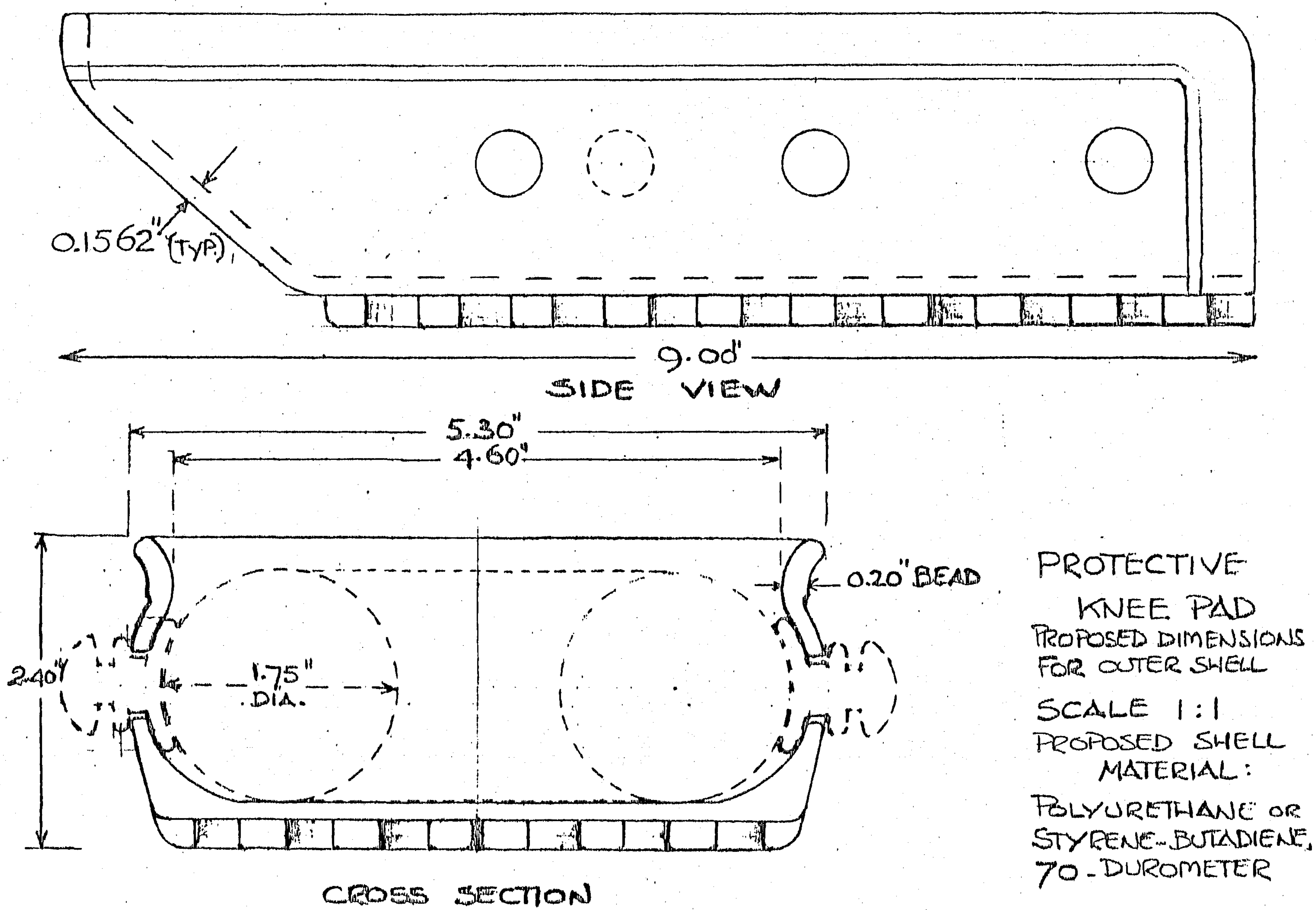

Figure 2. Dimensional drawing of the first prototype.

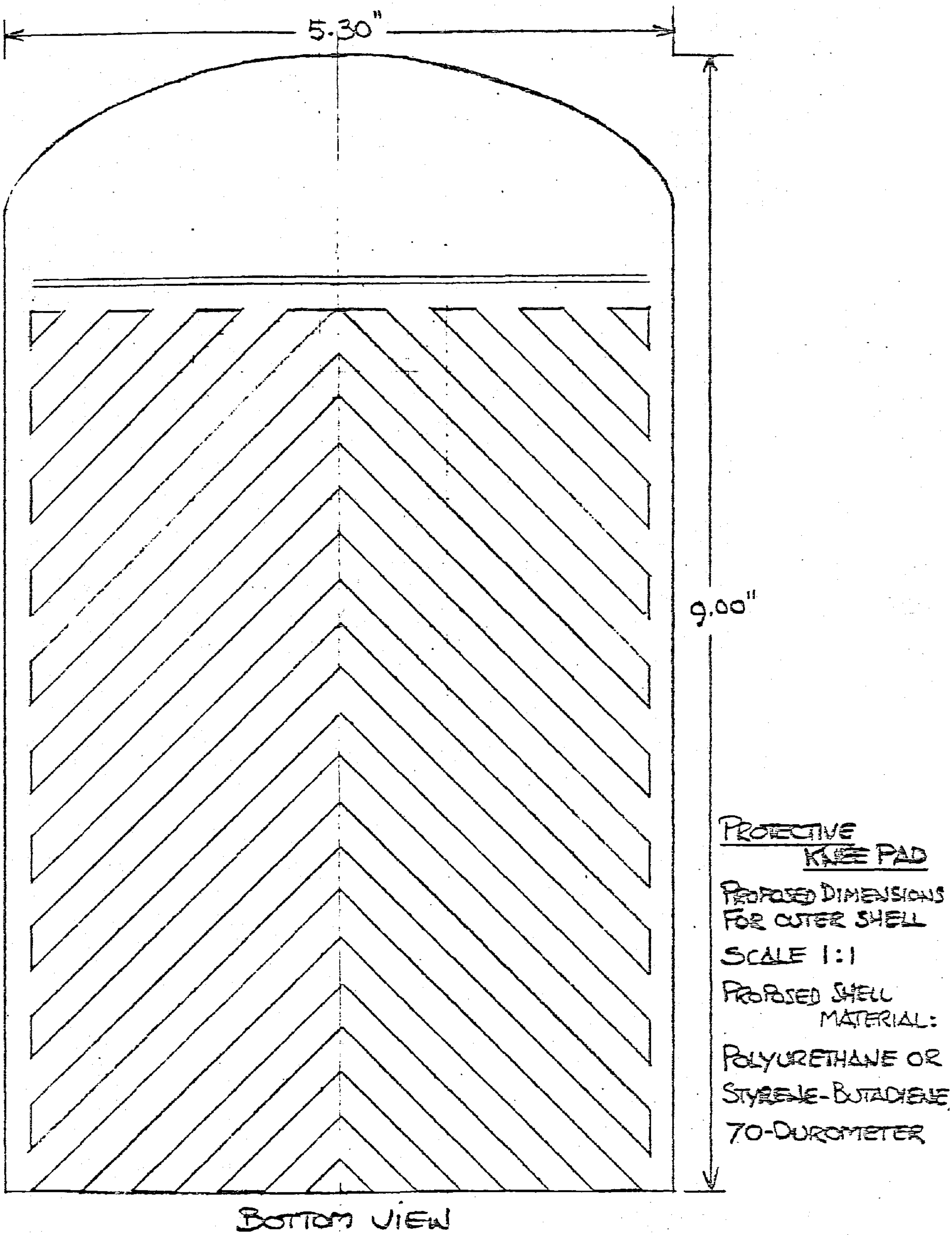

Figure 3. Dimensional drawing of the first prototype.

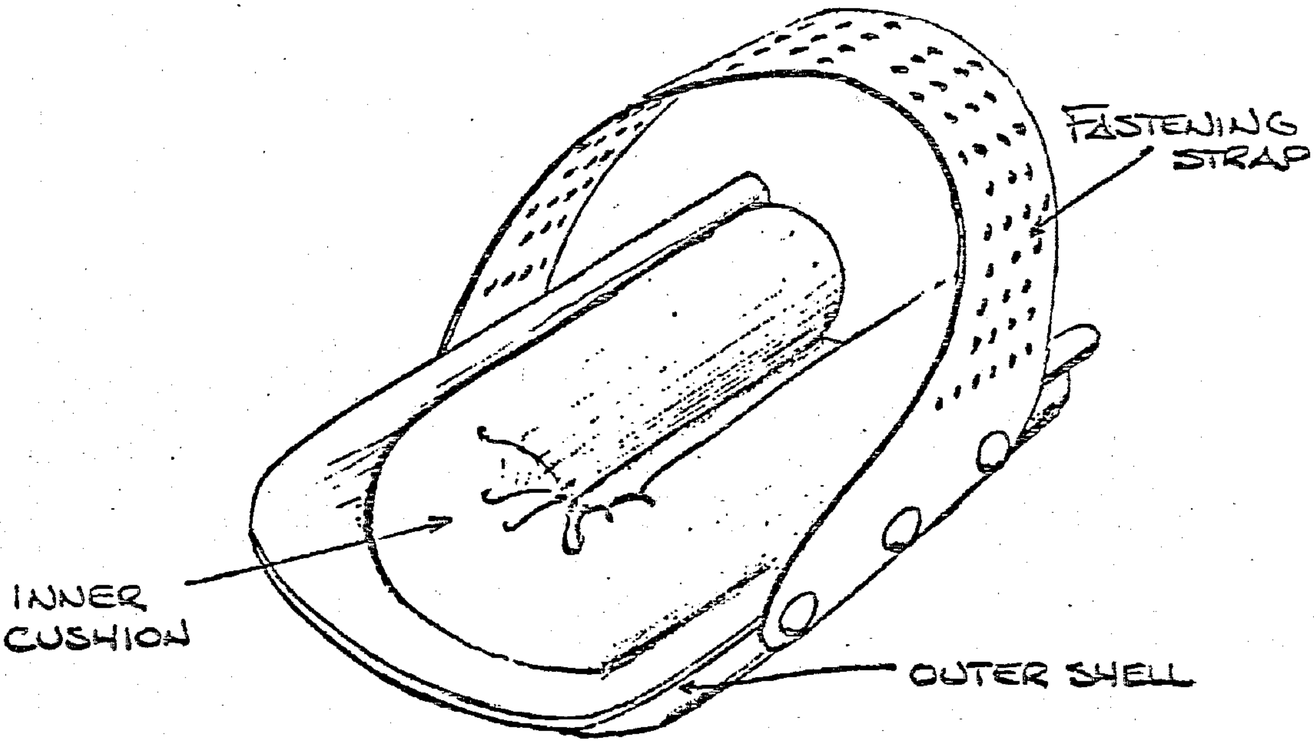

Figure 4. The complete knee pad assembly.

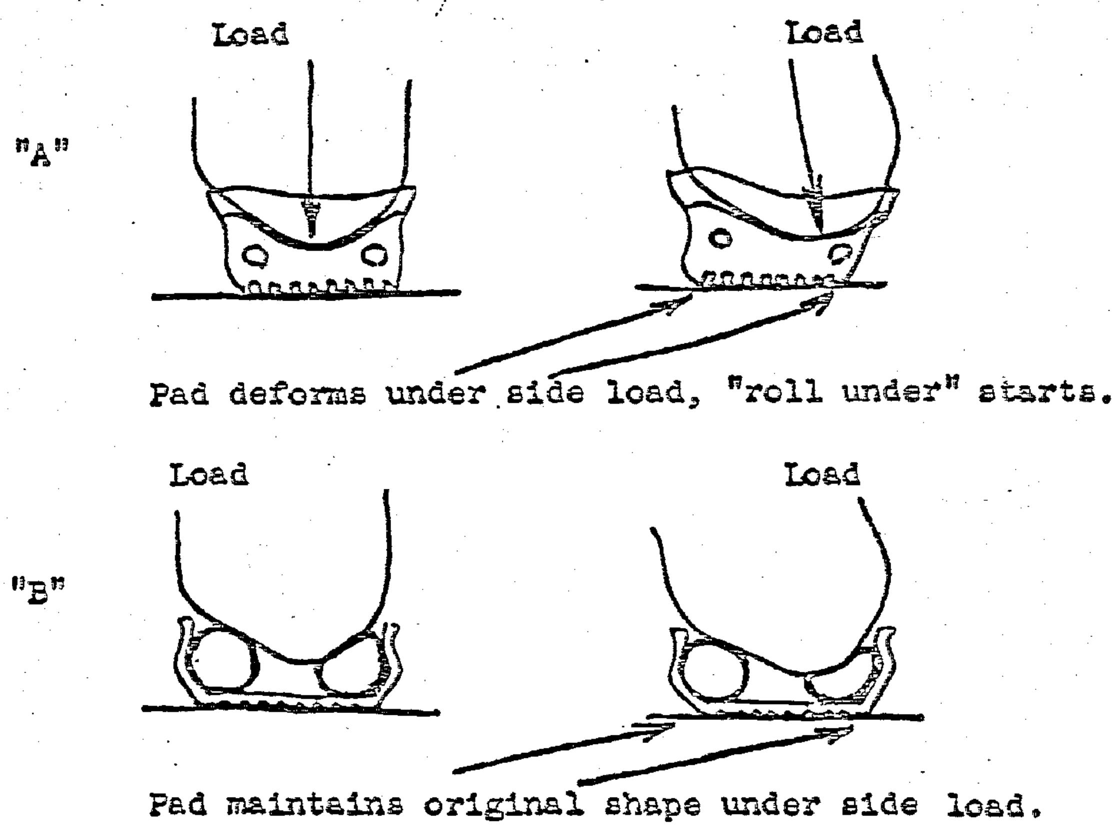

Figure 5. Effect of side load on high profile knee pads with flexible shell"A" and with semi-rigid shell "B". (From: Improved Knee Protective Devices for Mine Workers, Century Research Corporation, January 1972.)

and a single button placed somewhat forward of center on the opposite side. The strap was perforated for ventilation. (Figure 6) Three button holes allowed for selection of strap tension.

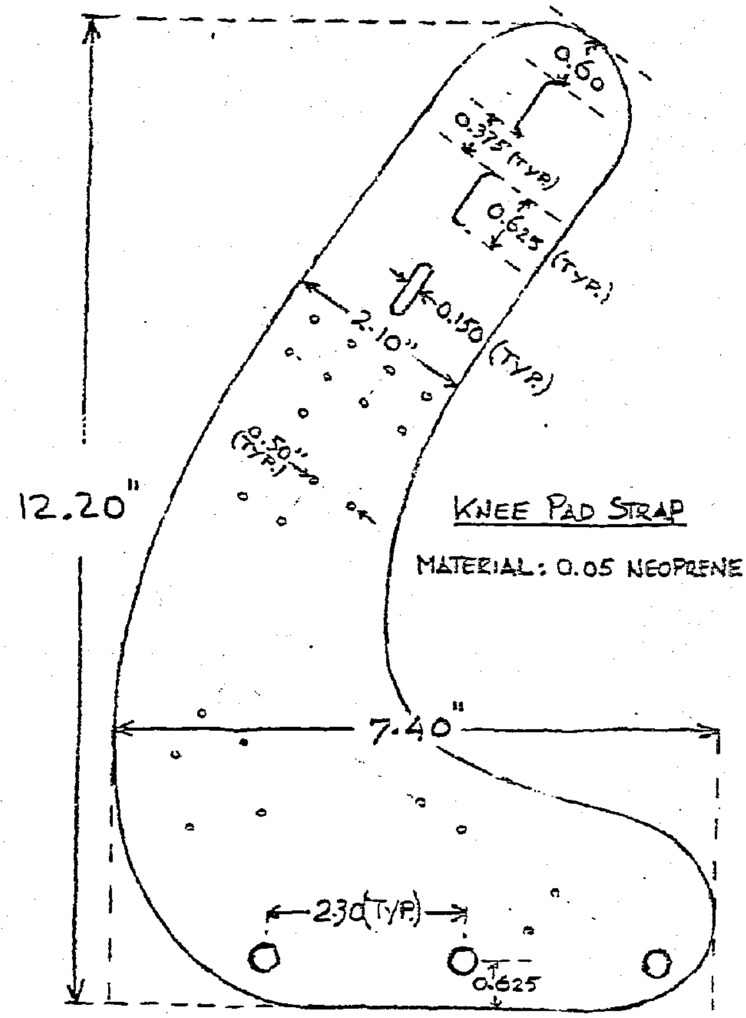

Figure 6. Fastening strap for the initial prototype.

Evaluation of the Initial Prototype

The above described design was never actually tested in the mines. The pads had been worn extensively by the developers, and found to be comfortable, relatively stable, and easy to put on and take off. It was decided, however, before assembling the required number of pairs for the in-mine evaluation, to have the design critically evaluated by several U. S. Bureau of Mines officials who between them had decades of low coal experience. The result of this evaluation was twofold: first, a decision was made to alter the design rather drastically before evaluating it in the mines; second, the initial test plan was discarded and a new procedure adopted.

The Initial Test Plan

Under the originally proposed test plan, ten volunteers from a likely source such as a local campus or military base, not necessarily knee pad users, would be asked to test the new knee pads in comparison with two presently available pads. The simulated environment would have consisted of a cinder track, covered by a 36" high mesh ceiling, with a work area at the end of the track. The work area, also under a 36" mesh ceiling, would contain a simple pipe structure to be disassembled and re-assembled, and a pile of mixed sand and gravel, to be moved six feet with the use of a shovel. Data acquisition would have been in the form of timed events, still and moving photography, and interrogation of the subjects regarding comfort of the knee pads tested. Data acquisition would have taken place over a period of one month. The whole subsequent analysis and write-up of findings, was to have taken two months.

Following the simulated tests, the analysis of the findings would be translated into design modifications if necessary. It was felt that any modifications required would probably be of a minor nature. The modified design would then be fabricated into 500 pairs of knee pads to be evaluated by 500 low coal mine workers in the actual mine environment.

The evaluation by the U. S. Bureau of Mines officials pointed up several undesirable features of the pads that were going to require major redesign, such as a drastic reduction in overall width, and a more moderate reduction in length; redesign of the front of the outer shell, making it higher, more form-fitting to the knee, thus reducing the likelihood of rocks, grit or mud entering the pad; a reduction of the diameter of the inner cushion; and reconsideration of the single strap design, which was not considered adequate to keep the pad straight on the wearer's knee under the more severe crawling conditions such as traversing piles of rock or lumber. Reduction of the overall size was considered of prime importance because of the potential danger of too bulky pads snagging on obstacles or moving machinery such as a conveyor belt.

As a result of these change requirements, it was decided that it would be unrealistic to assume that further testing would not produce further drastic modifications. Therefore it would be a waste of money, time and energy to produce 500 pairs of knee pads at this stage of development, and conduct such a rather large-scale evaluation as had been originally proposed.

The Revised Test Plan

It was then proposed that the simulated environment tests be dropped, as well as the plan for the single, large scale in-mine test. Instead, several small scale in-mine tests would be conducted, using 10 to 12 U. S. Bureau of Mines inspectors as volunteers for relatively brief (one week) test periods at a time. This required that only small amounts of prototype pads needed to be assembled, which allowed us to turn the fabrication and modification processes into in-house operations, independent from the schedules of other manufacturers and fabricators. After each test, the necessary changes could be made relatively quickly and easily and the next test begun.

It was proposed that an interview guide be used which was to be filled out by each volunteer after each day of testing. And a Century Research Corporation research team member would accompany a different inspector-volunteer into the mine every day, observing, making notes, taking still pictures and moviefilm shots of the evaluation. The resulting data would then be used to determine whatever design modifications were called for before the next evaluation took place.

Evaluation of the First Modification

As reported earlier, the outer shell of the initial prototype was reduced in length and in width, and its front end changed to make it fit the knee more snugly. (Figure 7) This in turn called for a smaller inner cushion; the diameter of the cylindrical inner cushion was reduced from 1 3/4" to 1 1/8", and its legs (the legs of the "U") were shortened. Two grades of firmness for this reduced foam cushion were tested, one soft, in the range of 2 - 5 PSI*, and one medium firm in the range of 9 - 13 PSI. In addition, it was decided to test a third cushion, having a square rather than round cross section. This cushion, also made of polyurethane foam, was 3/4" thick, and its firmness was in the 13 - 17 PSI range. (See Figure 8) Like the other cushions, it was horseshoe shaped and it had a tough smooth skin on its upper surface. The fastening method was modified as well;

*Pressure required to obtain 25% deflection.

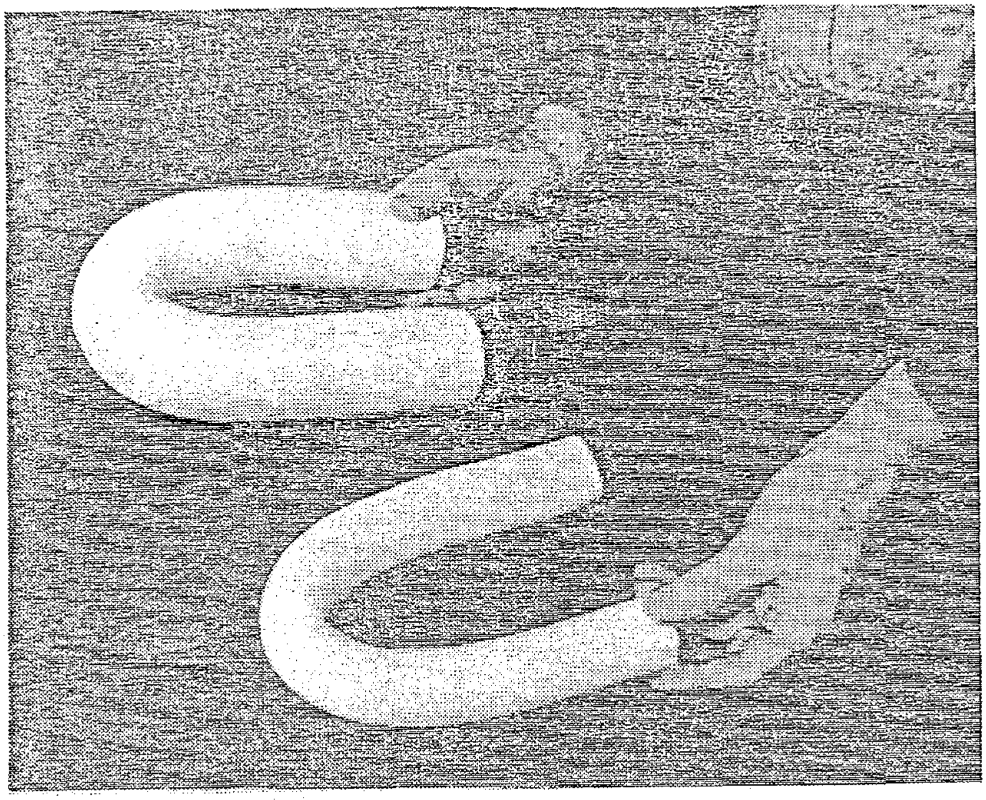

Figure 7. Comparison of original 1 3/4" dia. cushion and the reduced 1 1/8" dia. version.

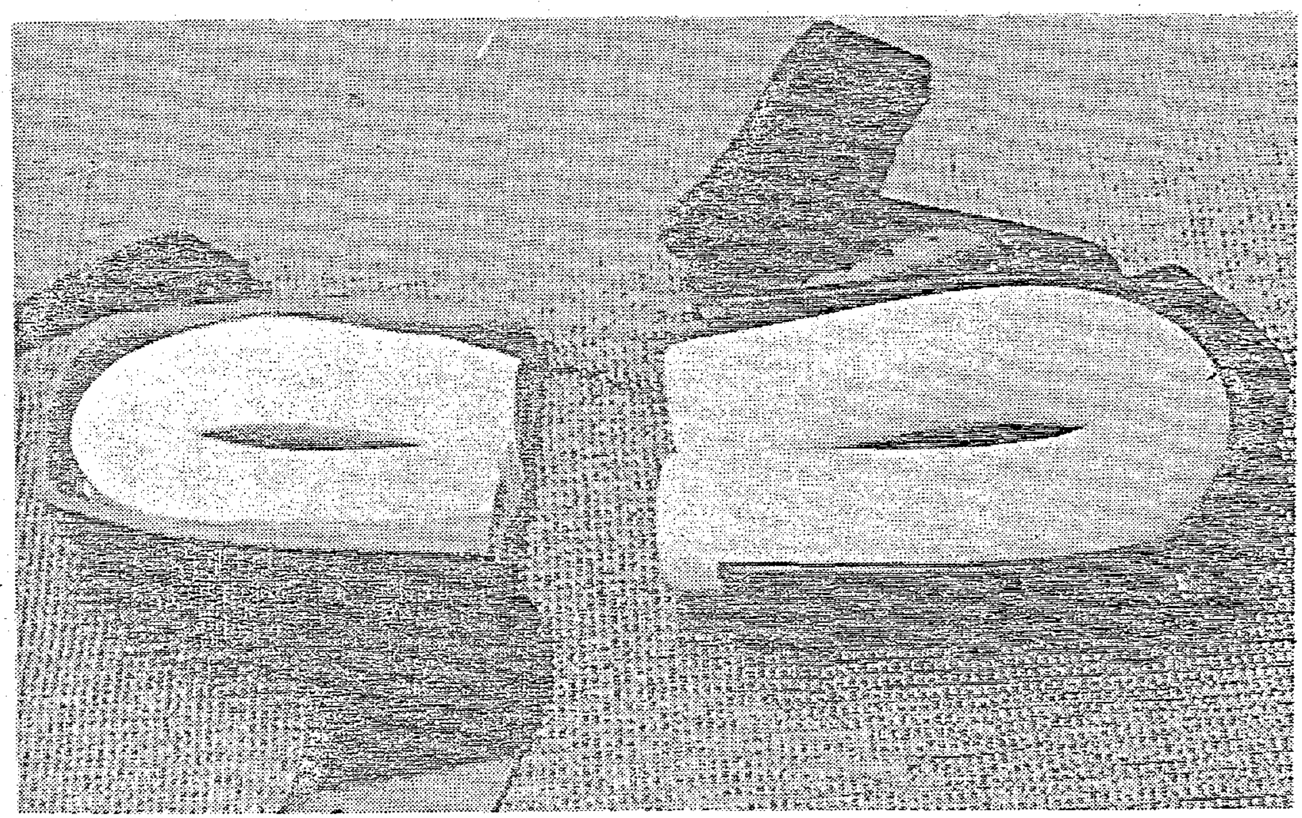

Figure 8. Comparison between initial prototype with modified front end, original cushion (right) and reduced size pad with square cross section cushion.

the single curved strap system became a two-strap system consisting of either two curved straps or a curved and a straight strap. Three fastening buttons on either side of the outer shell of the knee pad provided multiple possible fastening combinations.

The evaluation took place in the low coal mines in the Beckley, West Virginia area. During one work-week two Century Research Corporation research team members accompanied a different U. S. Bureau of Mines inspector, who was wearing a pair of the experimental pads, into a different mine each day, taking notes, still and motion pictures, and wearing a pair of the experimental pads themselves. After each day of testing, the volunteer inspector having worn the experimental pads that day was interviewed in detail about his opinion of the pads, with the aid of the interview guide. (See Appendix A, 1st Interview Guide.)

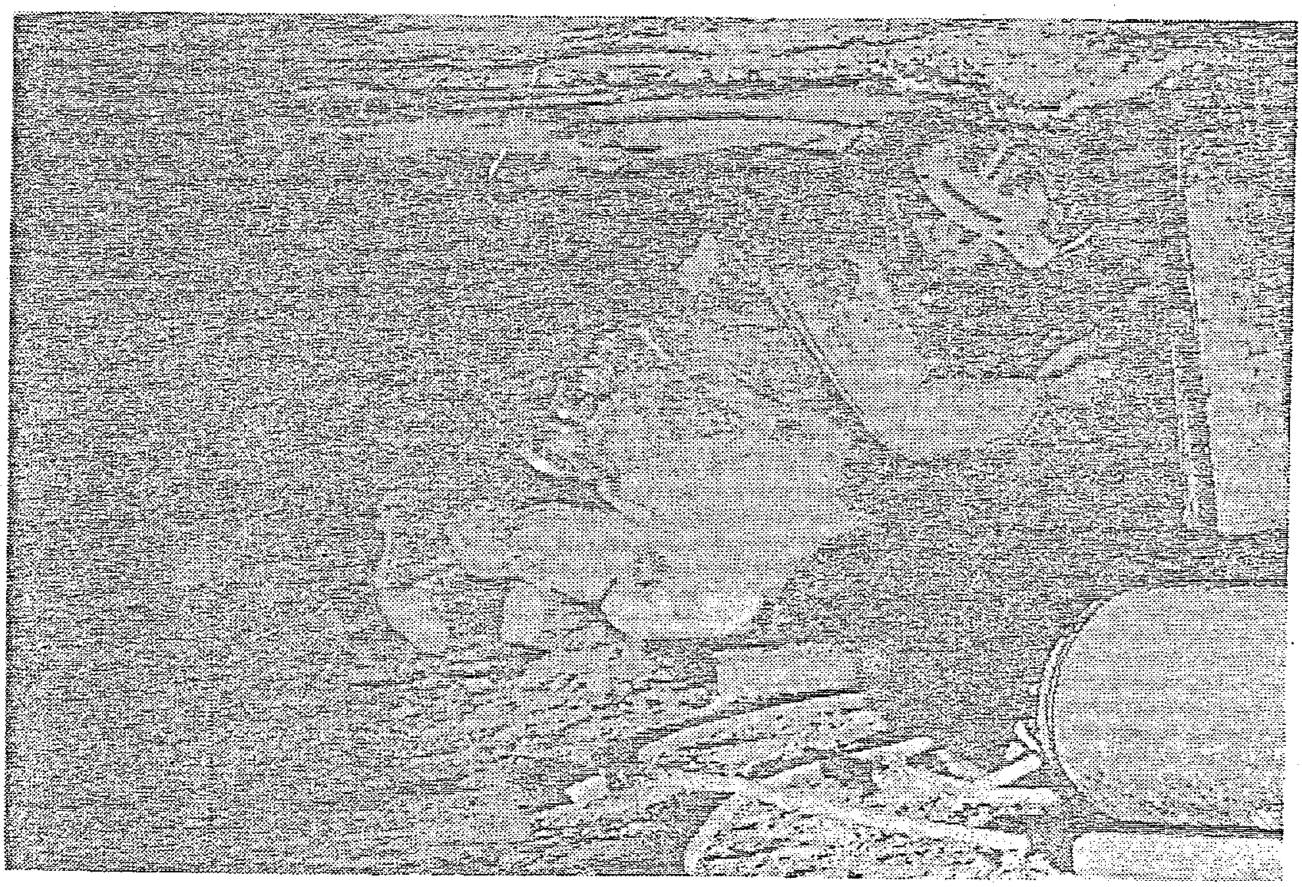

Figure 9. In-mine evaluation of the first modification of the prototype knee pads.

The first day, the cushions with the round cross section were abandoned in favor of those with the square cross section because of a tendency of the former to cause excessive friction on the wearer's knee, resulting in large blisters. The results of the rest of the evaluation were fairly consistent.

The pads rated high in comfort, both for the inner cushion and for the fastening straps. The principal objections were against a tendency for the pads to roll or twist on the knee, and the lack of a higher, even snugger fitting front "lip" or panel which would help to keep extraneous matter out of the pad and which was thought to counteract the rolling and twisting tendency.

The wide, curved fastening strap was well accepted for its relative comfort, but by itself it did not provide enough tension along the entire length of the pad to keep it from twisting. An additional (straight) strap that was used as an auxiliary support improved this situation somewhat but not entirely, and it more or less cancelled out the desirable features of the curved strap. The auxiliary straight strap concentrated much of its tension directly on the hamstring, a weakness of most fastening straps available today. Where an additional <u>curved</u> strap was used, the excessive bulk of the two wide straps caused discomfort behind the wearer's knees, and still did not completely prevent the pad from twisting. A fairly drastic re-design of the front end of the knee pads seemed indicated.

During these evaluations, various other aspects of the low coal mine environment and adaptations to it were observed and when possible were photographed, such as the floor surface that had to be crawled over; it ranged from four-inch deep fine dust to piles of lumber or stones to four-inch deep standing water, with many variations in between; the frequent necessity to crawl through narrow openings where even a slight amount of excess bulk in a knee pad became a severe hindrance; and the different manners of crawling of individual men, which may partially explain their individual preferences for different types of knee pads. (See Figures 10, 11, 12)

Development and Evaluation of the Second Modification

The major difficulties experienced with the knee pads tested centered around the lack of tension between the front end of the pad and the wearer's knee. This allowed the pad to swing out in the horizontal plane and occasionally position itself more or less diagonally on the wearer's knee. It also caused it to flop back and forth in the vertical plane, which in turn would cause the pad to snag on obstacles in the wearer's path. The most obvious solution to this problem would be a straight strap, attached far forward on the knee pad's outer shell, as on all commercially available miner's

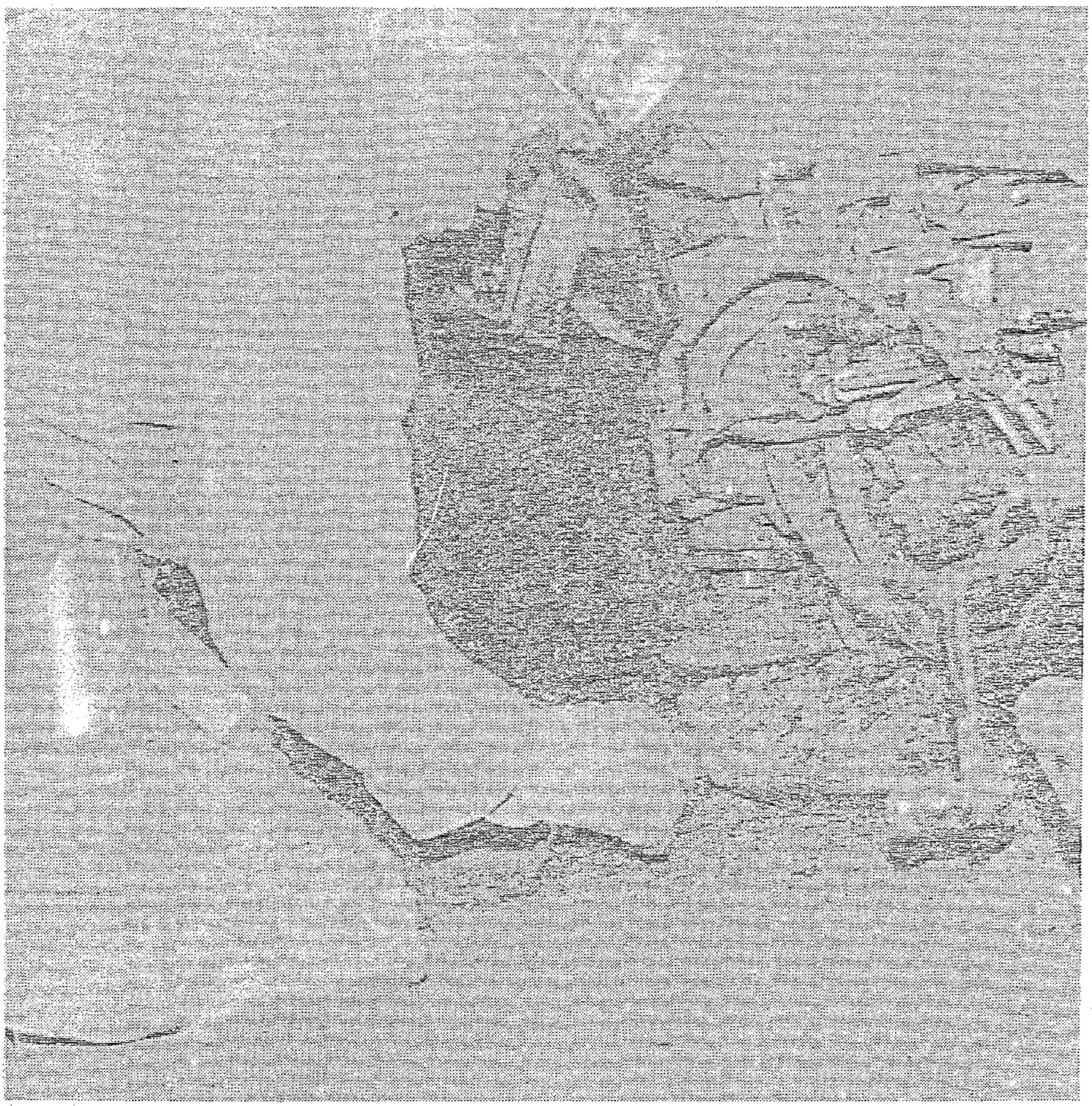

Figure 10. On uneven surfaces such as this thick layer of coal dust, the knee pad often twists sideways.

Figure 11. The low-coal miner often has to wend his way through close quarters like these.

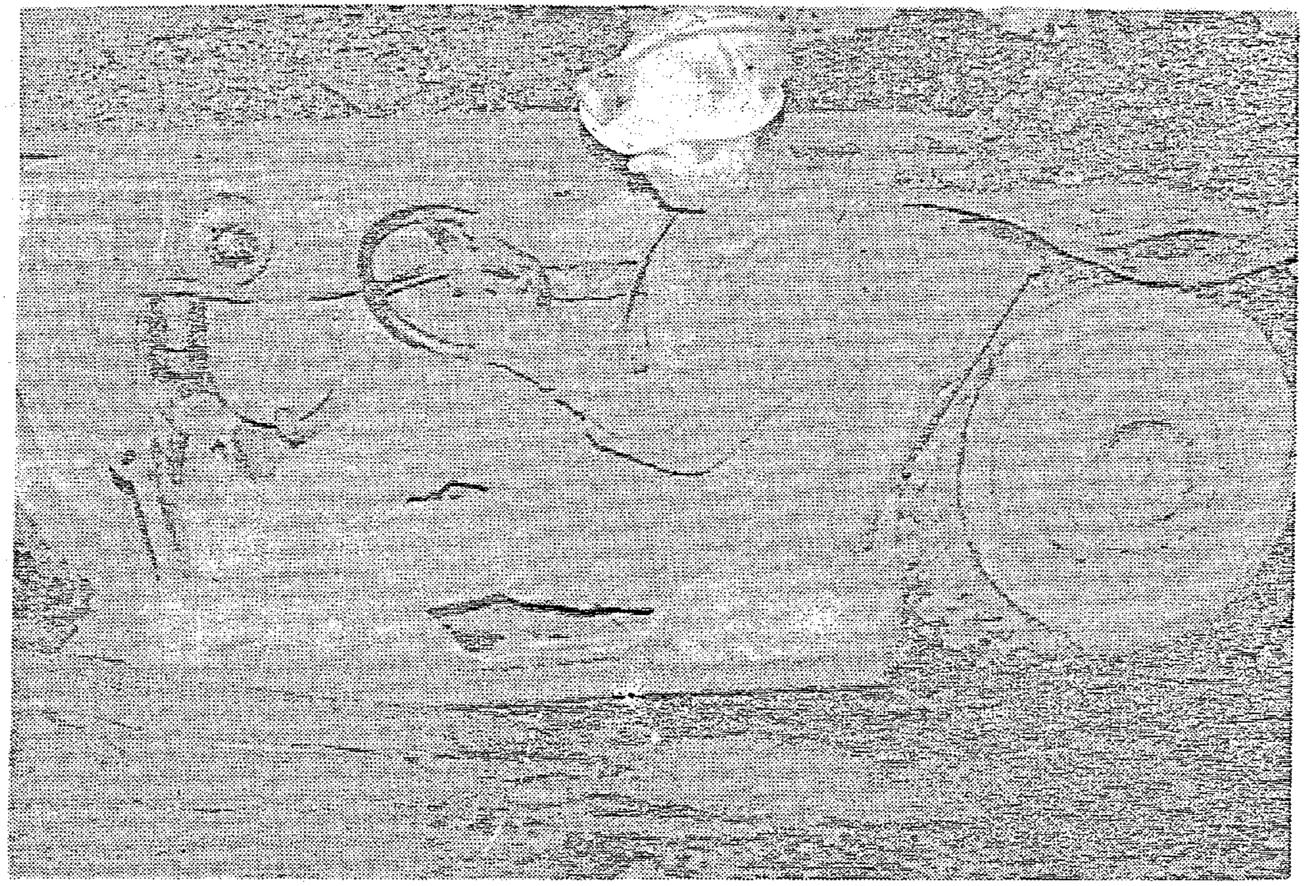

Figure 12. Deep mud, an often-encountered adverse floor condition.

knee pads. But such a strap had shown to be a source of discomfort where it presses on the hamstrings, and so another method was developed.

The idea of attaching the knee pads to the wearer's pants legs had been considered earlier, then abandoned as too complicated, since it involved modifying the volunteer's working clothes. This idea was now revived, and after some preliminary experimentation using strips of Velcro sewn to the pants leg with the mating strips fastened to the front of the kneepad, a method using zipper fasteners was developed. The Velcro fastening is shown in Figure 13. With the latter method, one-half of a heavy duty jacket zipper, approximately 8" long, was sewn across the front of the pants leg of the wearer's coverall slightly above the knee. An 8" wide by 6" high sheet of 1/8" thick rubber (truck innertube material) was securely fastened to the front end of each knee pad, and the other half of each zipper attached along the top edge of this sheet as is shown in Figure 14.

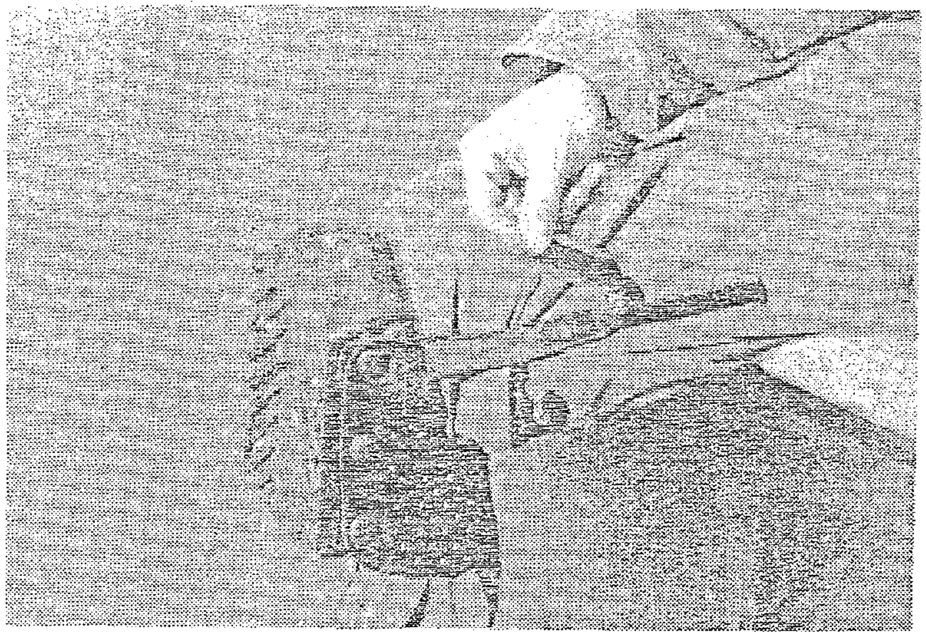

Figure 13.
The first attempt to attach knee pad to clothing was with two Velcro strips.

Figure 14. Zipper knee pad-to-coveralls fastening method.

The wide curved strap was again used to fasten the pad in the rear, and by closing the two zipper halves together, the pad was securely held against the knee while standing or crawling. The elasticity of the rubber sheet allowed for the difference in tension while bending or stretching the knee. The other advantage of this approach was that the rubber sheet prevented rocks, mud and grit from entering the front of the pads, a common complaint of many knee pad users. Considerable thought was given to the problem of how to make the height of the rubber sheet adjustable, to allow for the difference in individual knee sizes. The earlier approach with the Velcro strips allowed for such adjustment, but two strips did not provide enough stability to the front end of the pad. The sturdier rubber sheet did, with eight continuous inches of attachment, but adequacy of adjustment remained an unsolved problem.

It was decided to attempt to custom-fit the zipper halves on each inspector's coveralls while the inspector was wearing the coveralls, so they would be positioned as correctly as possible. This was done, and twelve pairs of inspectors' coveralls were outfitted with zipper halves across the pant legs.

A modification of the inner cushion was also made at this time. This modification consisted of lowering the profile slightly and increasing the stability by building up the material thickness along the outside of the cushion, thus forming even more of a cradle or cup for the knee to rest in than before. The basic horseshoe shape of the cushion was retained. This is shown in Figure 15.

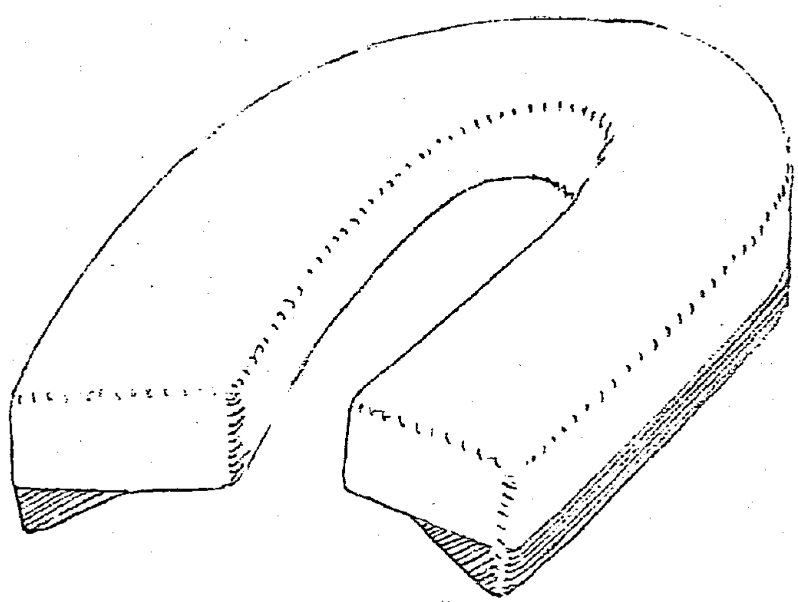

Figure 15. Cushion modification, showing peripheral build-up on bottom.

The evaluation again took place in the low coal mines in the Beckley, West Virginia region. Twelve inspectors of the U. S. Bureau of Mines 4th District in Mount Hope, West Virginia volunteered to wear the pads during the performance of their daily inspection duties. The evaluation was conducted over a two-week period, during which a Century Research Corporation staff member was on location, accompanying a different inspector into a different mine each day to observe the performance of the knee pads under a variety of conditions, and to take photographs.

The inspectors participating in the evaluation were asked to write down their opinions, findings and recommendations on a prepared form immediately after testing the new knee pads. (See Appendix B, 2nd Interview Guide.)

Those volunteers who expressed willingness to continue with the evaluation were asked to wear the knee pads as often as possible for the next several weeks until either the knee pads or components thereof, or the condition of their knees, made it advisable to halt the evaluation. These men were given abbreviated forms to fill out at the end of each day of testing. The use of these pads is shown in Figures 16-19.

An analysis of the evaluation produced the following results:

(1) The fastening method using a zipper to attach the knee pads to the wearer's coverall pant legs was met with mixed reactions; the exact location of the zipper on the pant leg was so critical that a fraction of an inch could spell the difference between success and failure. In some cases, the coveralls used were brand new and hadn't been washed and shrunk to the wearer's exact size. As a result, more excess material tended to bunch up inside the knee pad than in the case of used, more snugly fitting coveralls. This caused friction on the wearers' knees as well as a tendency for the knee pads to move about under the wearer's knees as is shown in Figure 20.

Exact location of the zippers on the coverall legs proved to be critical in all cases, regardless of the condition of the coveralls, due to the loose fit of coveralls in general. In the over-all rating of the zipper fastening method, 11% rated it as excellent, 0% rated it as good, 55% gave it a rating of fair, and 33% thought it a poor method.

Figure 16. In-mine evaluation of the second modification.

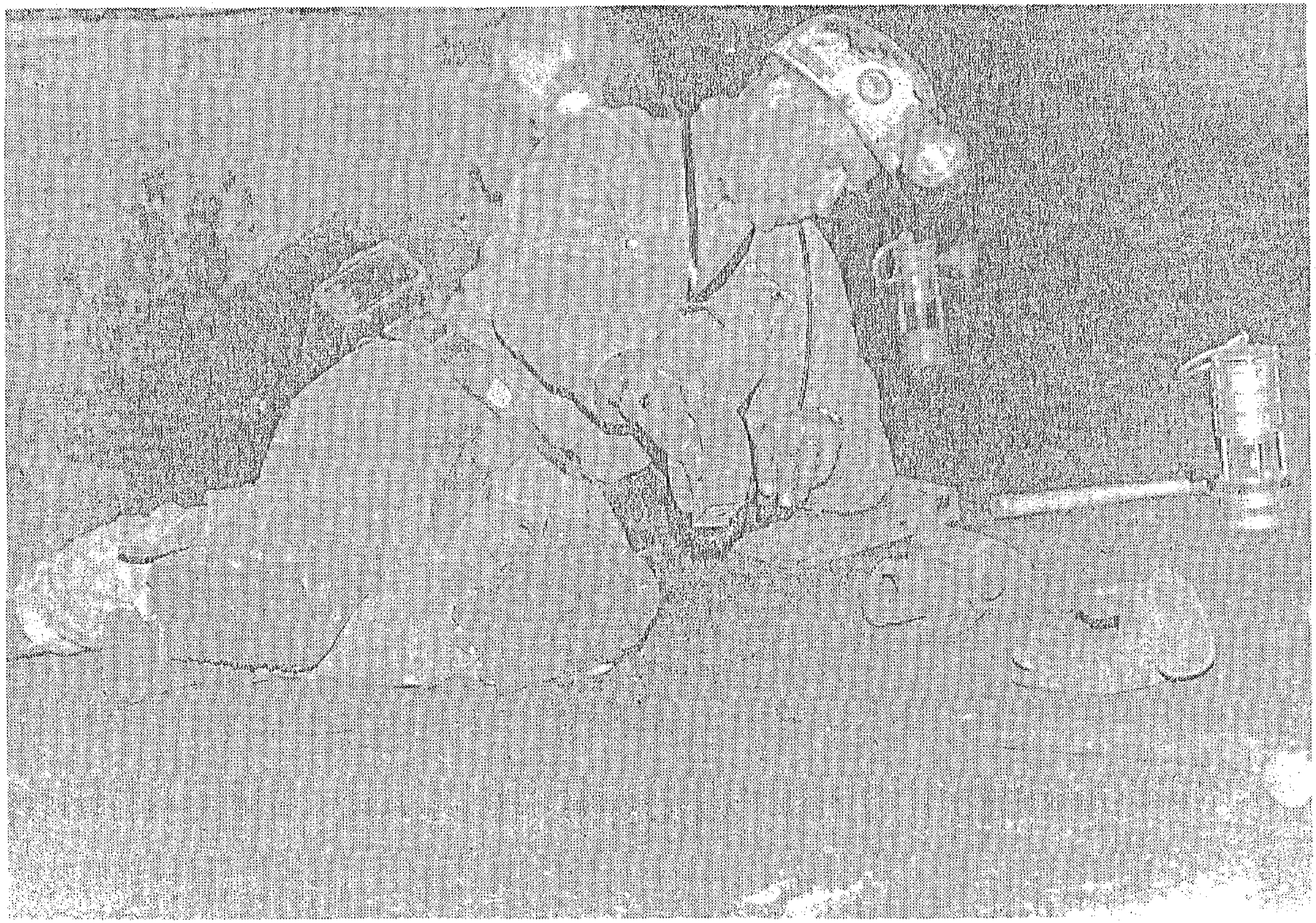

Figure 17. High side walls on knee pads are useful in positions such as this.

Figure 18. The rubber knee pad-to-coverall attachment had to be elastic enough to stretch while kneeling and retain some tension while standing.

Figure 19. One of the principal reasons for discontinuing the integrated knee pad/coveralls approach was the very loose fit of the inspectors' coveralls.

(2) Two types of inner cushion materials were evaluated: a soft (2-5 PSI to 25% deflection) and a medium firm (9-13 PSI), both in two configurations: low profile and high profile. The high profile cushion was approximately 0.15" thicker than the low profile one. It became apparent that although the soft cushion was initially well liked for its comfort, it caused too much friction between it and the wearer's knee in the high profile version, and tended to "bottom out" in the low profile version, allowing the wearer's knees to touch the bottom of the outer shell. The cushions made of the firmer material proved to be the better choice. The low profile cushions were much preferred. The thicker ones tended to cause friction, and the wearers reported a tendency of the pads to "buckle" or slip out from under the knees on uneven terrain.

(3) In all other aspects that were evaluated, the knee pads performed adequately. They were rated high in comfort, the straps did not chafe or bind, the pads kept the wearers' knees dry in wet mines, and little or no grit or other foreign matter entered the knee pads. Figure 21 gives photographic evidence of these merits.

On the basis of the above results, it was decided to abandon any fastening methods that used the wearer's clothing as an anchoring point. Possibly, if tight fitting, e.g., stretch pants, were available this method would be feasible. In this case, though, design thinking went back to the two-strap fastening system. And with the rubber shield removed, the problem of the too low front end of the knee pads returned. And an improved method to retain the inner cushion inside the outer shell was needed. It was concluded that it was time for a somewhat complete redesign, rather than further modifications of the initial prototype.

Development of the New Experimental Pad

A thorough review was initiated of all the previous evaluation results, critiques and suggestions from experienced knee pad users, and of earlier adopted design approaches as well as rejected ones.

The results of the last in-mine evaluations had pointed up the need for a number of modifications in the design of the outer shell, the fastening method and the inner cushion.

Figure 20. The zipper fastening method allowed this pad to slide sideways on the wearer's knee.

Figure 21. The zipper fastening method kept this inspector's knees dry after crawling through standing water and mud.

It also became obvious, as a result of these tests, that the original outer shell, which had already been narrowed and shortened and otherwise modified after previous evaluations, had served its purpose and that a new shell was needed, whose design was based on all the previously gained test experience.

The new outer shell design differed considerably from the shapes used in the earlier experiments. Design sketches are shown in figures 22, 23 and 24. The principal feature changes were:

(1) Overall length was reduced by $1\frac{1}{4}$", to 7". Our findings indicated that the extra extension below the knee did not increase the afforded protection nor improve wearer comfort enough to justify the extra bulk.

(2) Width of knee pad's bottom or sole was reduced by 3/4". The wide sole of the original outer shell was based on the theory that it would provide greater stability, reducing the tendency for the pad to roll out from under the wearer's knee. Subsequent evaluations showed that the wide sole does provide good stability on relatively flat surfaces, but that the added bulk which is a result of that wide sole became a significant hindrance when crawling over very uneven surfaces such as piles of shale or timbers, a frequent occurrence in the mines.

(3) The front wall of the outer shell was heightened by $1\frac{1}{2}$". Its shape was rounded both in plan view and in elevation. The original outer shell did not have sufficient height at this point to prevent entry of rocks and grit. The forward edge of the sole of the earlier models was straight rather than rounded, rising to a bluntly pointed "bow." This configuration caused gaps on either side of the knee. The new outer shell had a flexible snug-fitting contoured front designed to keep out foreign matter. The rounded, snug-fitting exterior of the shell was designed to minimize snagging when crawling over obstacles.

(4) Fillets between side walls and inner sole of the pad were enlarged, making the shell more form-fitting on the inside, even

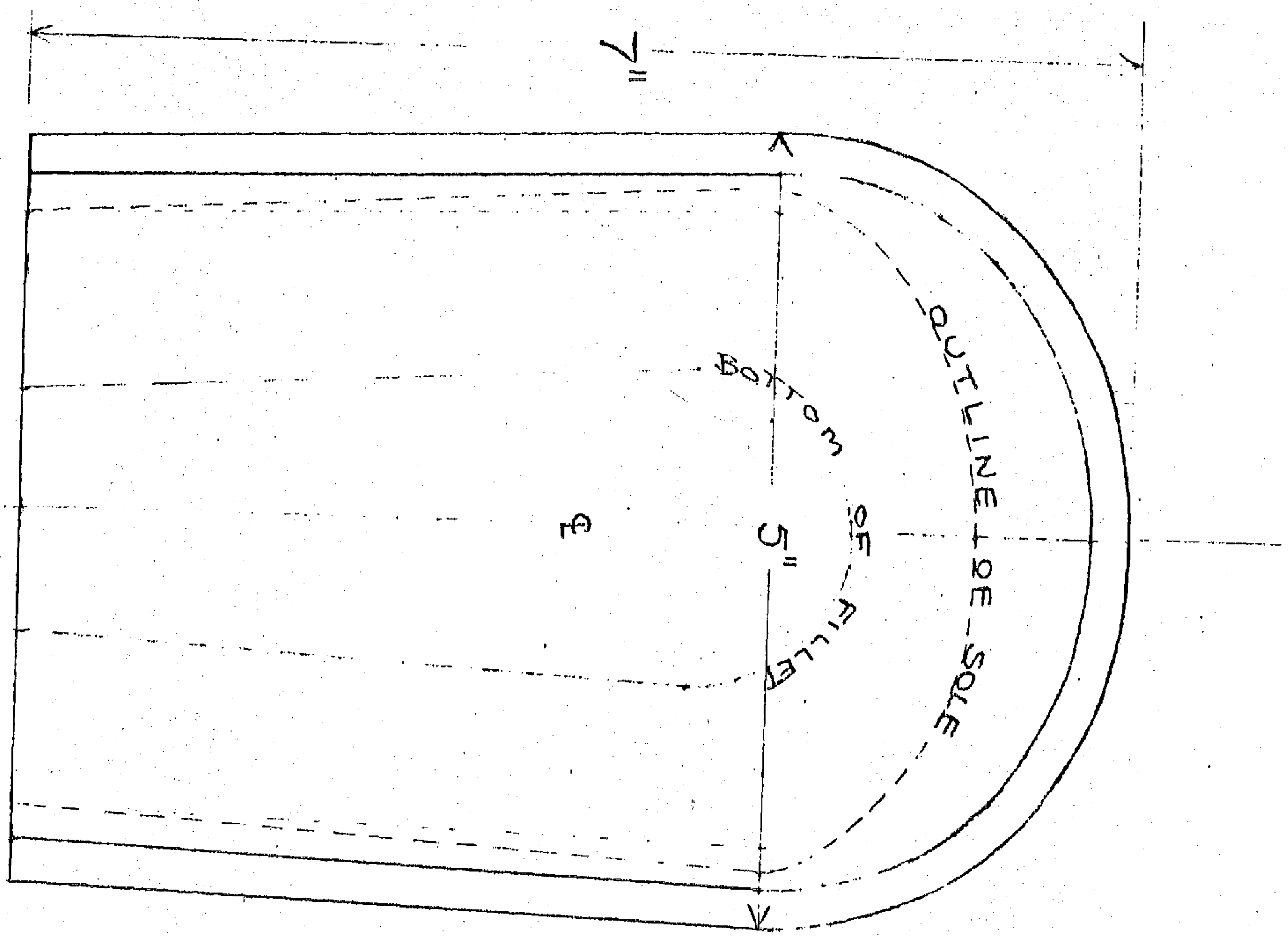

FIGURE 22.

HSM 99-72-81
PROTECTIVE KNEE PAD
TOP VIEW AND DIMENSIONS
OF OUTER SHELL

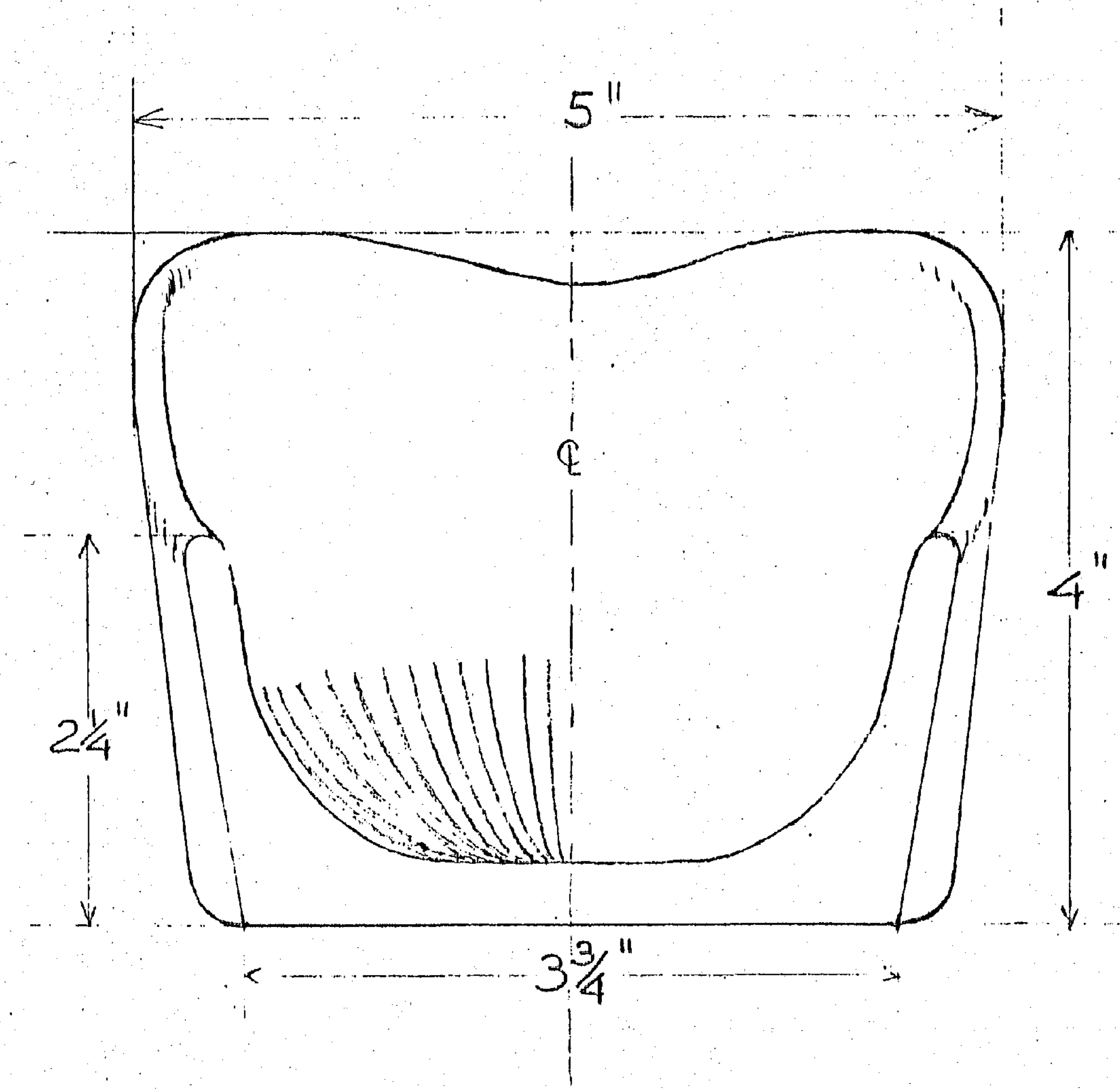

FIGURE 23.

HSM 99-72-81
PROTECTIVE KNEE PAD
REAR VIEW AND DIMENSIONS
OF OUTER SHELL

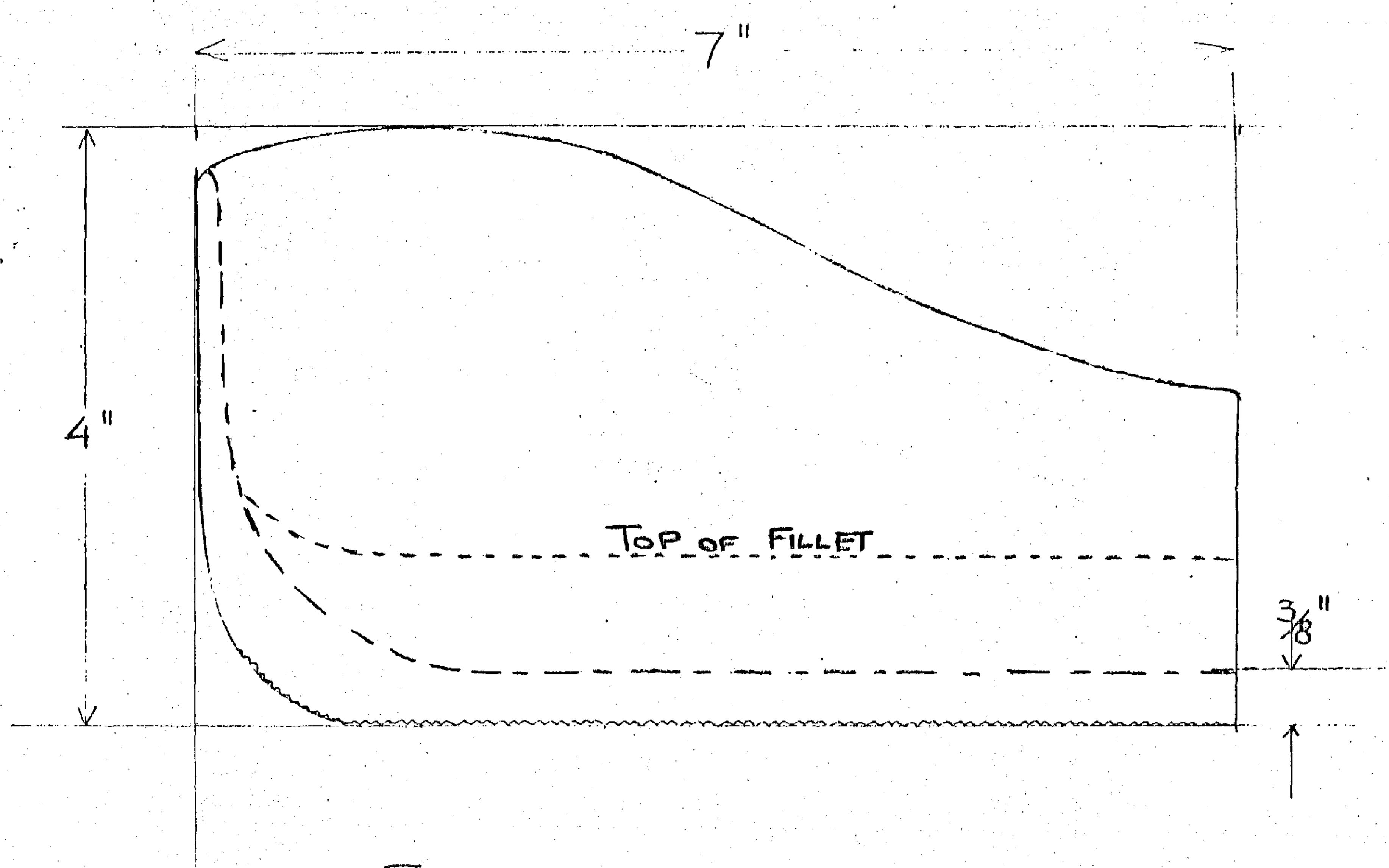

FIGURE 24.

HSM 99-72-81
PROTECTIVE KNEE PAD
SIDE VIEW AND DIMENSIONS
OF OUTER SHELL

without the inner cushion. During the last in-mine evaluations, it had been found that the tendency to roll out of the pad was significantly decreased when the inner cushion was reinforced around its bottom perimeter with a fillet of denser material than the cushion itself, which reduced movement of the knee within the outer shell. This fillet was now incorporated in the outer shell, in order to keep the design of the inner cushion as simple as possible.

(5) Tread pattern was changed to a simpler and finer textured pattern. It had been found that the deep V grooves in the earlier models collected inordinate amounts of sticky mud and grit. Furthermore, it had become apparent that the need for any treads at all was questionable. The new tread design had shallow, closely spaced lateral grooves. The differential adherence of mud and grit is shown in Figure 25.

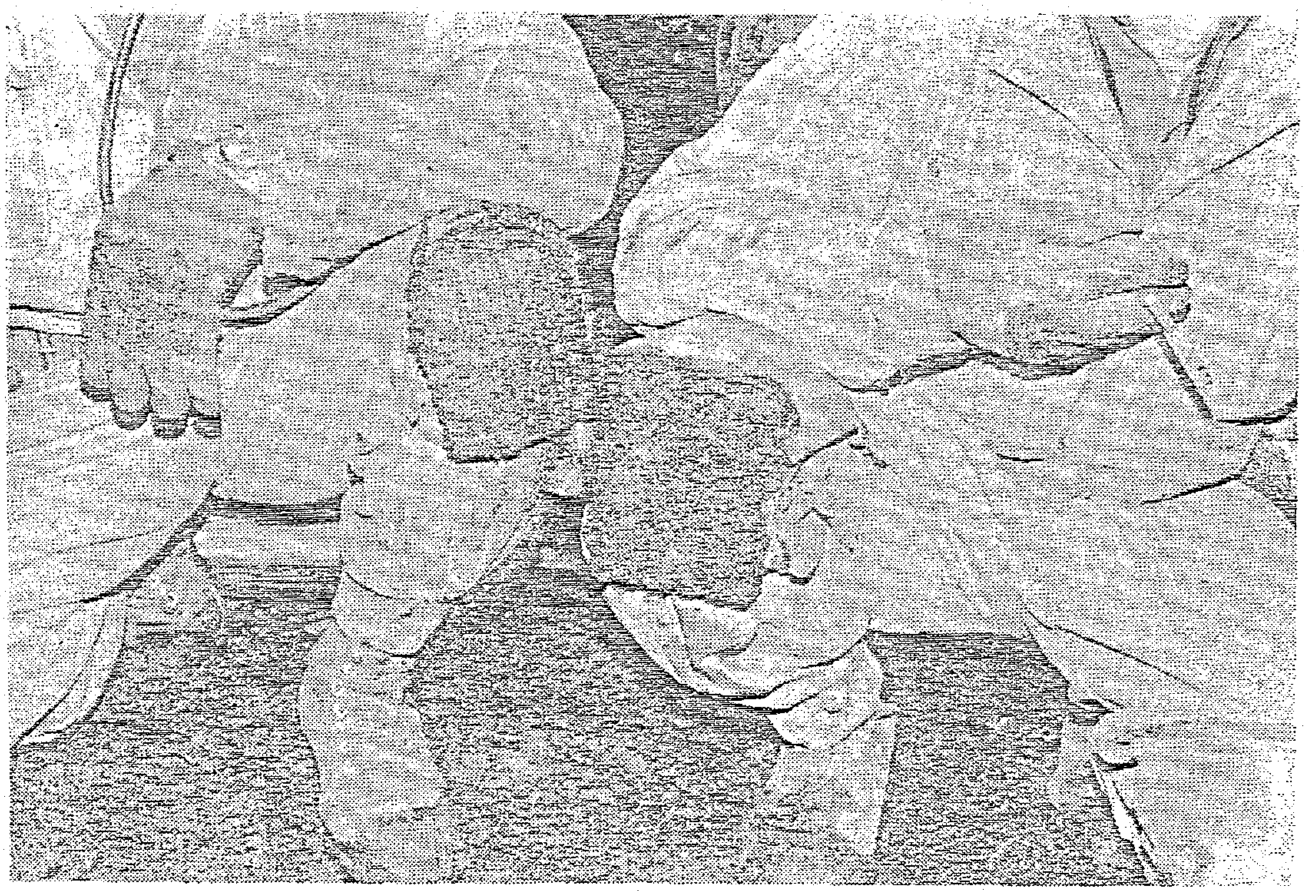

Figure 25. The deep tread on the experimental pad (right) collected more grit and mud than other pads. (On left a German Nierhaus standard pad.)

Besides the redesign of the outer shell, work on a new fastening method continued. It was found that the comparatively snug fit of the new pad required less tension on the front of the pad to keep it from twisting on the wearer's knee, and some hopeful experimentation was done with the single curved strap. It still did not provide adequate fastening, however, and experimentation with two-strap systems continued.

Meanwhile, a relatively new material on the market had come to our attention. It was a urethane elastomer that was marketed in two parts, a resin and a curing agent which, when mixed in the proper proportions, could be cast and cured at room temperature. This material, called Flexane and manufactured by the Devcon Corporation of Danvers, MA, came in several durometers, one of which (Devcon 85) lent itself very well to casting the outer shell for the knee pads.

A mold was made from silicone rubber, and from then on the pads were entirely manufactured on our own premises. Besides saving considerable money that would otherwise have been spent on a steel injection mold, this development made it feasible to make changes in the outer shell design as we went along, and made us independent from the time schedules of sub-contractors. One minor drawback of the new material was its weight, about 35-40% more per unit volume than the SBR (Styrene Butadiene) that the earlier, injection molded shells had been made of. But weight had earlier been shown to be a relatively unimportant consideration, and since no lighter material with similar properties was found, Flexane was chosen.

The first cushions to be tried in the new shells were identical to the ones that had shown promise during the first evaluation, horseshoe shaped, with a square cross section, approximately 3/4" thick, and with a firmness in the 13-17 PSI range.* A special type of rubber button was cast to keep the cushion in place and simultaneously serve as a fastener for the front strap. This button was similar to the rubber mushroom-shaped buttons that had been used throughout earlier tests, only its shank, connecting the thin, wide flange on its one end with the mushroom-shaped cap on the other, was lengthened by ½".

Further experimentation with this cushion led to a model that was perforated, to provide better ventilation, thus reducing sweating and the likelihood of blistering or other irritation to the wearer's knee.

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*The later configuration of this cushion, which had extra material added around its bottom periphery (See Figure 15) was not used here because the inside of the new outer shell was shaped so as to obtain the same desired effect of stability.

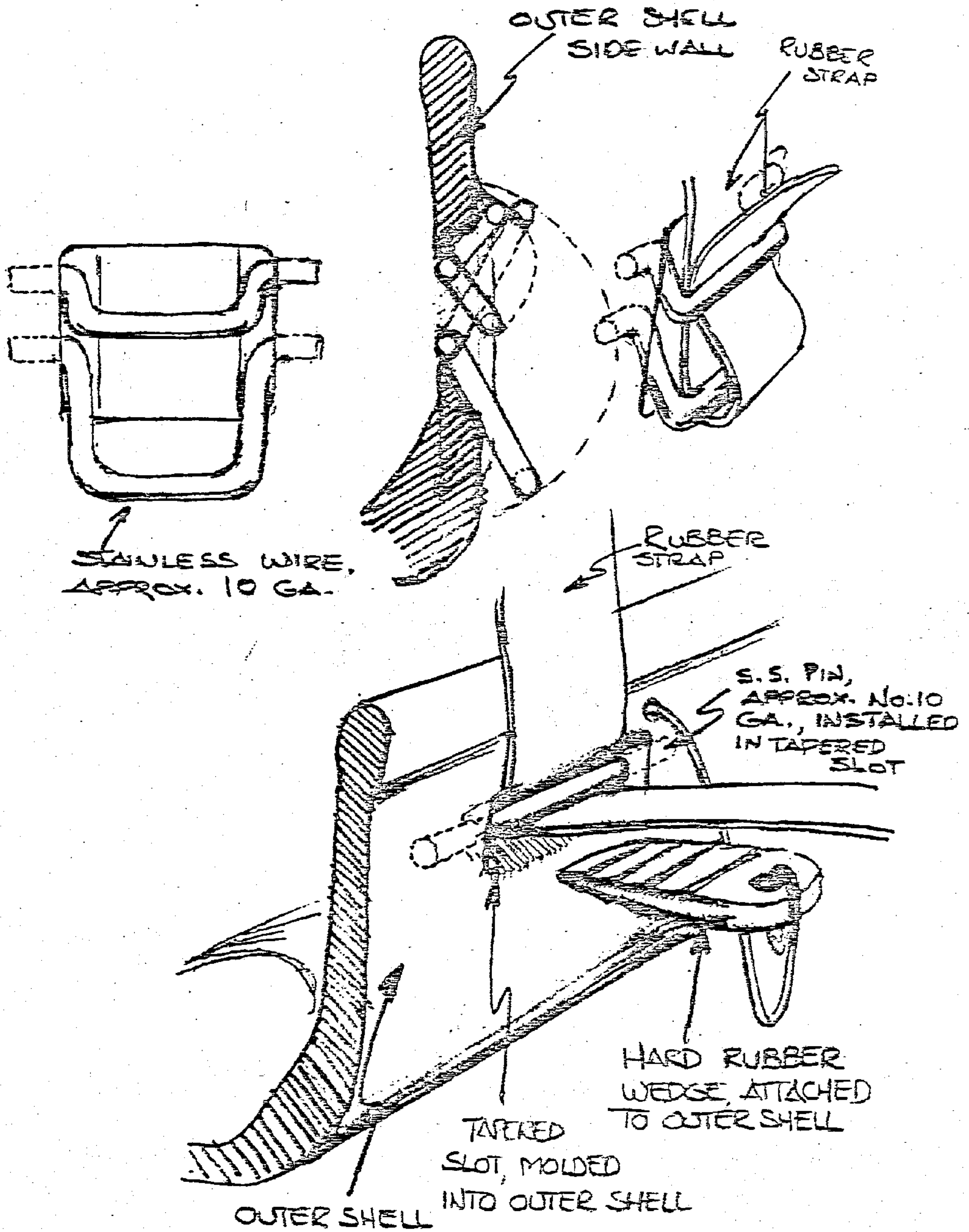

Figure 26. Experimental methods of continuous adjustment for knee pad fastening straps.

It had been found that straps using a continuous or "infinite" adjustment system were thought to be more comfortable than those using adjustment by increment as did our straps with the three "button-holes." It was thought that if a return to the top strap across the hamstrings was indicated, an attempt should be made to make this strap as acceptable as possible to the wearer by providing it with the continuous adjustment fastener. Two propotypes of such a fastening system were made. Figure 26 shows sketches of them. It was found that although such fasteners work well with leather, cloth or other non-elastic materials, they did not hold with rubber straps. It was then decided to go back to the rubber button system, but to provide the straps with three button holes on each end, with 1" spacing between the three holes on one end, and 3/8" between three staggered holes on the other end, giving 9 possible combinations instead of 3*.

The idea of a fastening system avoiding contact with the hamstrings had not been completely abandoned, and an approach using two straps appeared to have possibilities. It consisted of a wide (2") relatively thick bottom or back strap across the upper calf, and a narrower (3/4"-1") top or forward strap which was laced through two slots near the center of the back strap in the manner shown in Figure 27.

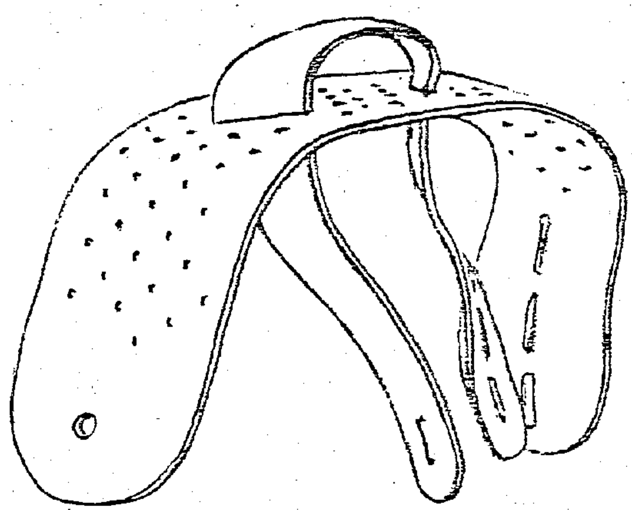

Figure 27. Interlaced front and rear straps.

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*At the time this idea was first brought up, another approach using interlaced straps had already been partially implemented. Since this latter approach dealt with the problem of the pressure on the hamstrings, which was considered more urgent than the adjustment problem, it was decided to equip the test pads with the interlaced straps.

The top strap was thus held out of the knee crotch where irritation to the hamstrings is the greatest. Since this approach was the most promising of the fastening systems that had been tried out, it was chosen to be fitted to the new pads for the next evaluation.

The Third (Comparative) Evaluation

During the entire R & D process, many different types of commercially available knee pads had been acquired for study, for measurements, and for testing purposes. Some of these were in common use in the mines where our tests took place and others, of foreign manufacture, had, to our knowledge, never been imported into this country. It was known, from observations, interviews and casual talks, that a clear preference scale existed towards different knee pads among all the low coal mine workers we observed or talked to.

In order to affirm this, and to establish a standard against which our experimental pads could be judged, the next evaluation was set up as a comparative one, in which nine different types of knee pads were judged against one another by nine volunteers, again U. S. Bureau of Mines inspectors from the 4th District in Mount Hope, West Virginia. The pads to be compared consisted of three U. S.-made ones, three German-made ones, two British-made ones and the Century Research Corporation experimental pads. Mine inspectors were to test each of the nine pads once, in random order, and in a time period as close to nine consecutive days as possible. As before, each inspector was asked to fill out an evaluation form at the end of each day of testing. This time the form contained 0 to 10 rating scales for various aspects of the pads tested and for the overall rating. The test was set up according to a Latin square as follows:

Test Day	1	2	3	4	5	6	7	8	9
				Pad order					
Inspector's name:									
B	E	H	I	C	F	A	B	D	G
C	F	I	A	D	G	B	C	E	H
K	G	A	B	E	H	C	D	F	I
McK . . .	H	B	C	F	I	D	E	G	A
M	I	C	D	G	A	E	F	H	B
P	A	D	E	H	B	F	G	I	C
R	B	E	F	I	C	G	H	A	D
V	C	F	G	A	D	H	I	B	E
W	D	G	H	B	E	I	A	C	F

Each letter represents a different type of knee pad, as follows: (See Figures 28 through 37)

A Judsen, U. S.

B NMS "Knee-Eze", U. S.

C Rockmaster, U. S.

D Nierhaus "Standard", German*

E Nierhaus "Lightweight", German*

F Nierhaus "HD", German*

G Crason "Airwell", British

H "Bursa", British

I CRC Experimental

(See Appendix C, Rating Form.)

The Appendix contains the different types of forms used throughout the evaluation, in chronological order. Some detailed questions that appeared in earlier forms were eliminated in later ones, and some questions thought pertinent that hadn't appeared in the earlier versions were added in the later ones. The single page form was used by those inspectors who volunteered to keep testing an experimental pad after the designated test period was over.

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* These pads, sold under the trademark "Wohltat," are referred to by the manufacturer as the box type, the pleated type, and the special type, respectively. We refer to "D" as the standard type because it is the only one of the three that is in common use in the W. Va. mining region.

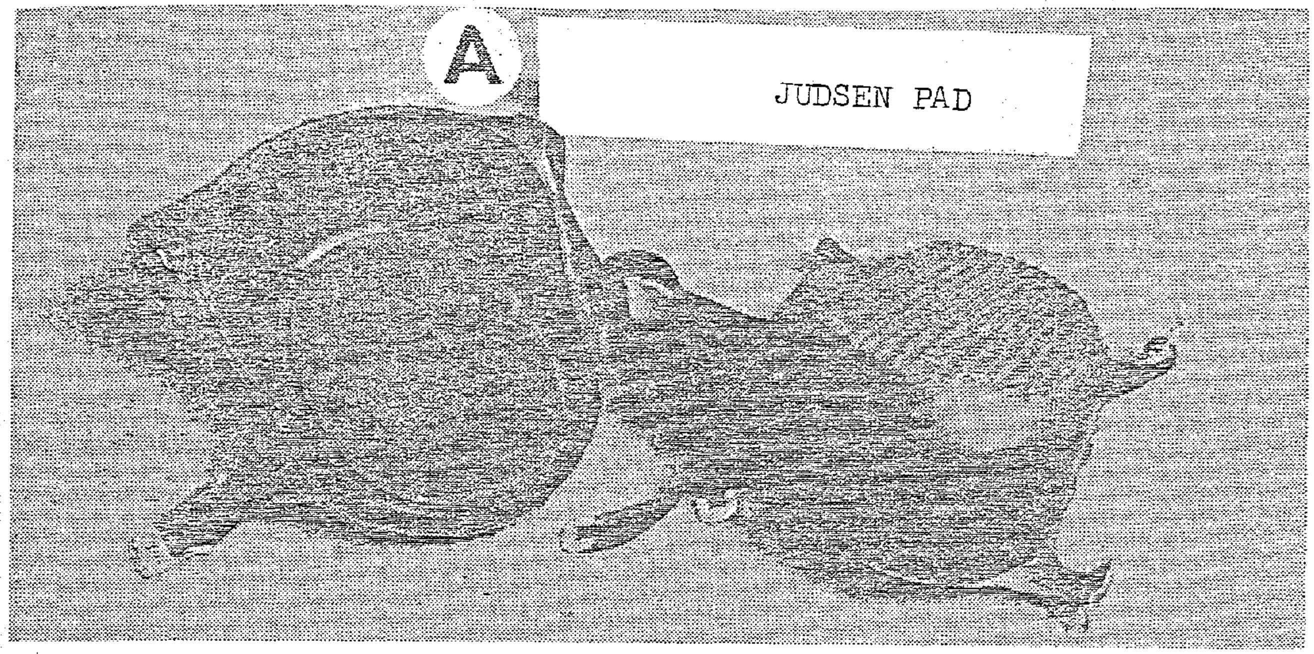


Figure 28. Judsen pad. U. S. made, the least expensive of the pads tested. It has a $\frac{1}{2}$" thick cushion, is of light-weight construction, has cloth straps.

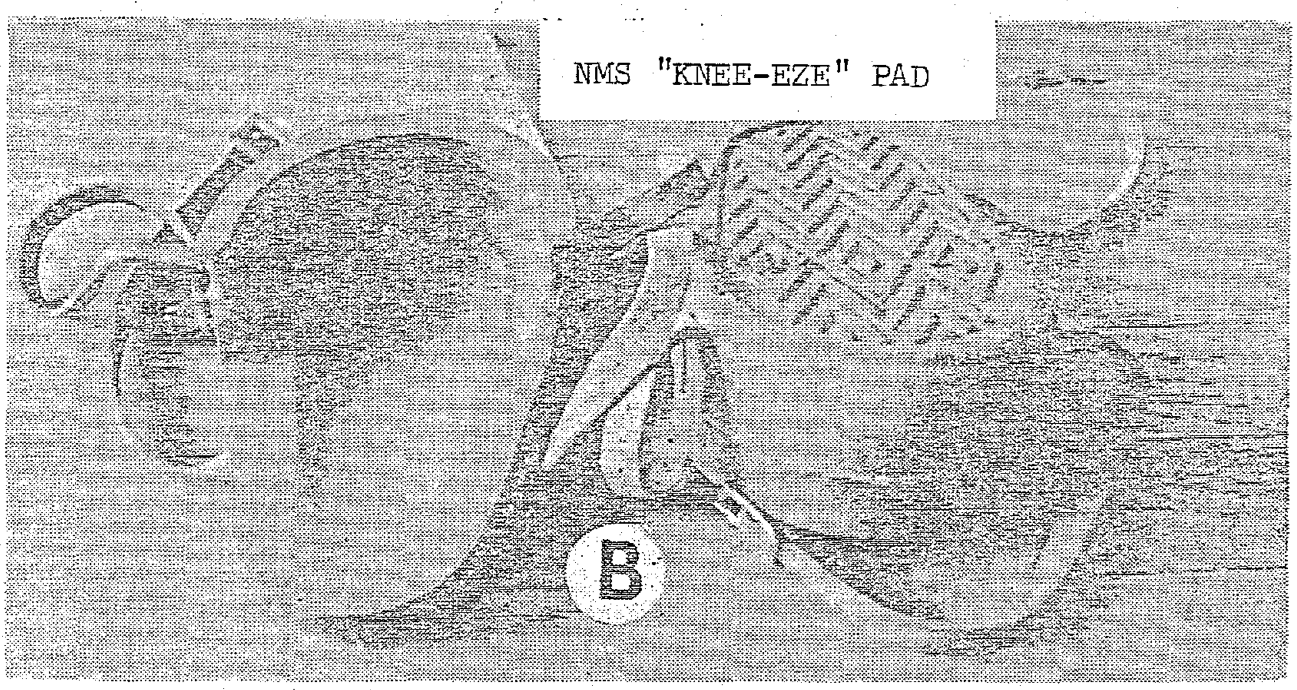


Figure 29. NMS "Knee-Eze" pad. U. S. Made. Of one-piece construction, 1" thick, this red sponge rubber pad is currently standard issue to the U. S. Bureau of Mines. It comes with either leather or web straps.

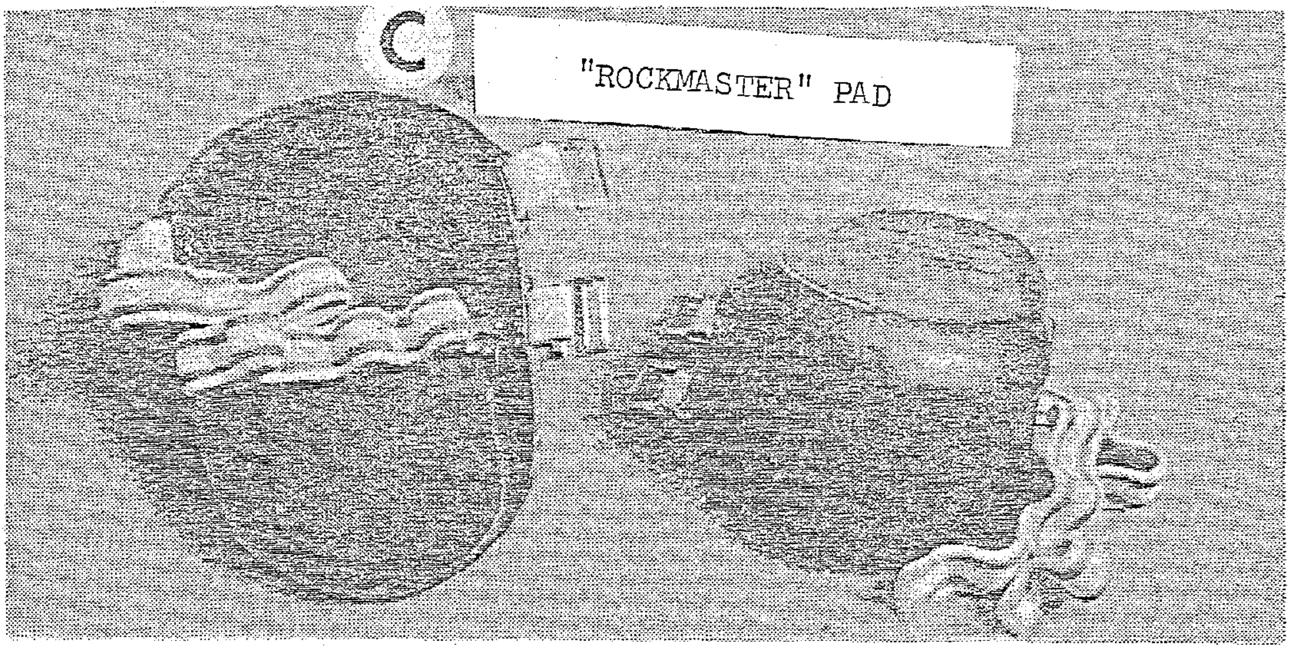


Figure 30. "Rockmaster" pad. U. S. made. Comparable construction to the Judsen pad, but heavier duty, with thicker (5/8") cushion, and with elastic woven straps.

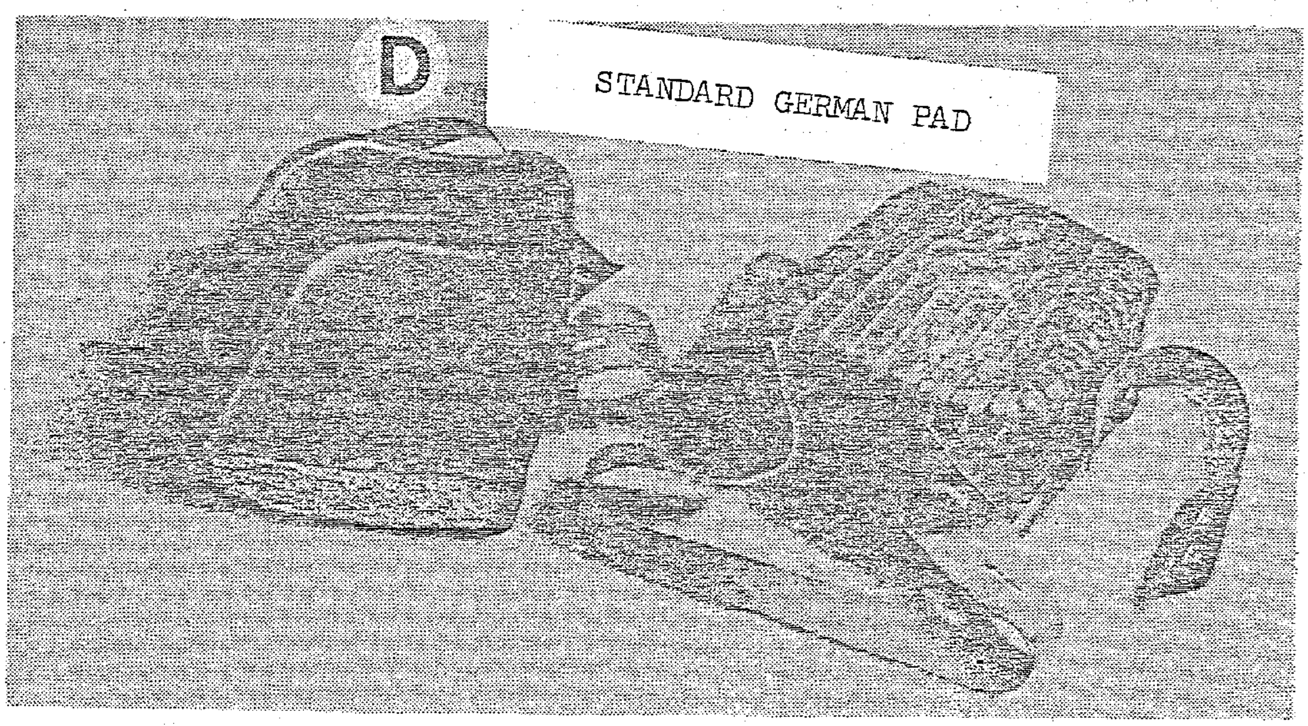


Figure 31. Nierhaus standard type pad. German made. $1\frac{1}{2}$" thick sponge cushion, rubber straps.

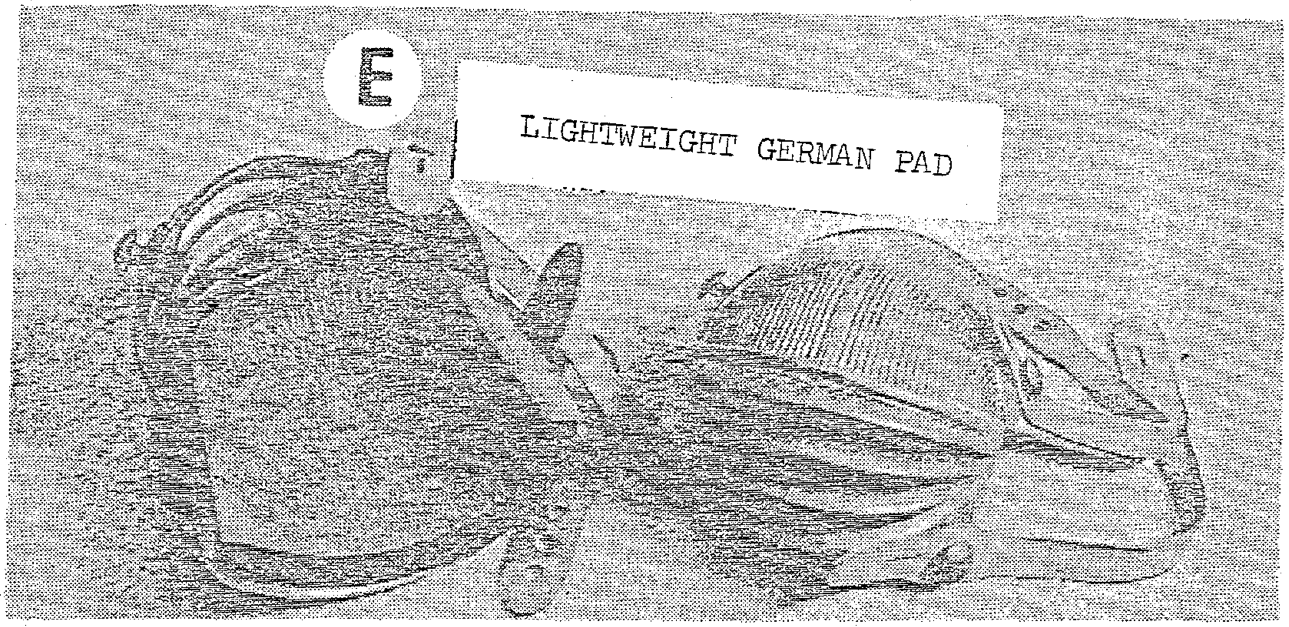


Figure 32. Nierhaus lightweight pad. German made. Rounded bottom, 5/8" thick sponge cushion, pleated front, rubber straps.

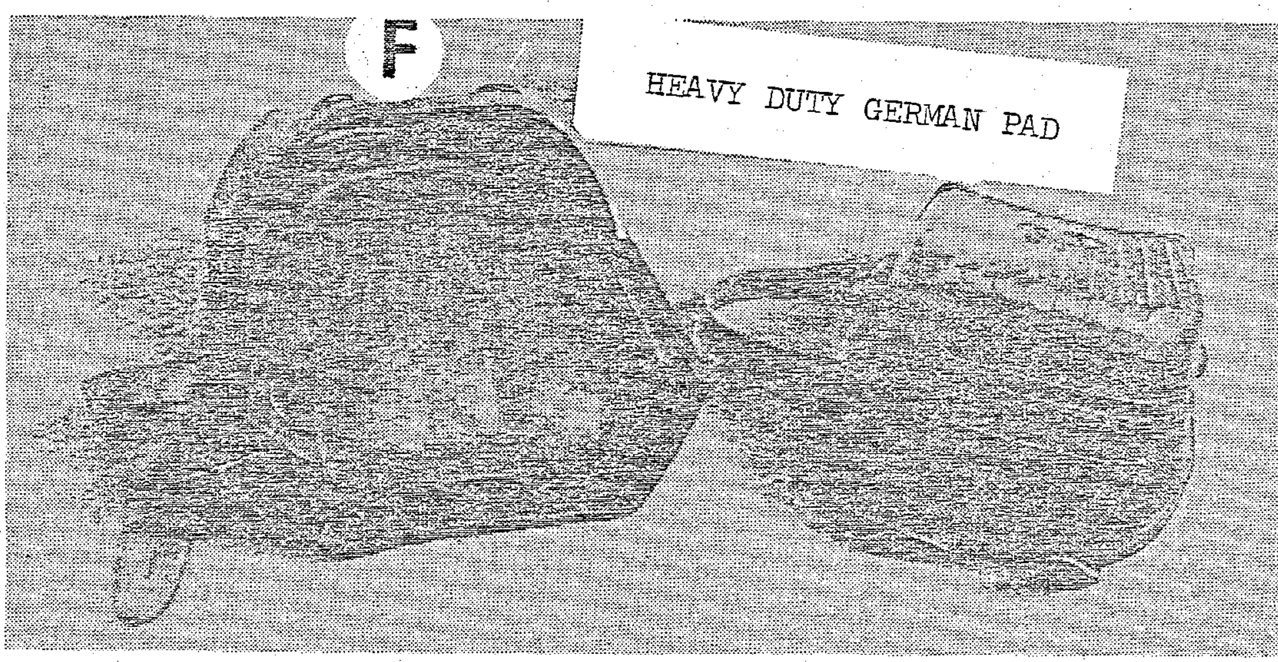


Figure 33. Nierhaus heavy duty pad. German made. Has high, curved-in front, approximately $1\frac{1}{2}$" thick cushion, rubber straps.

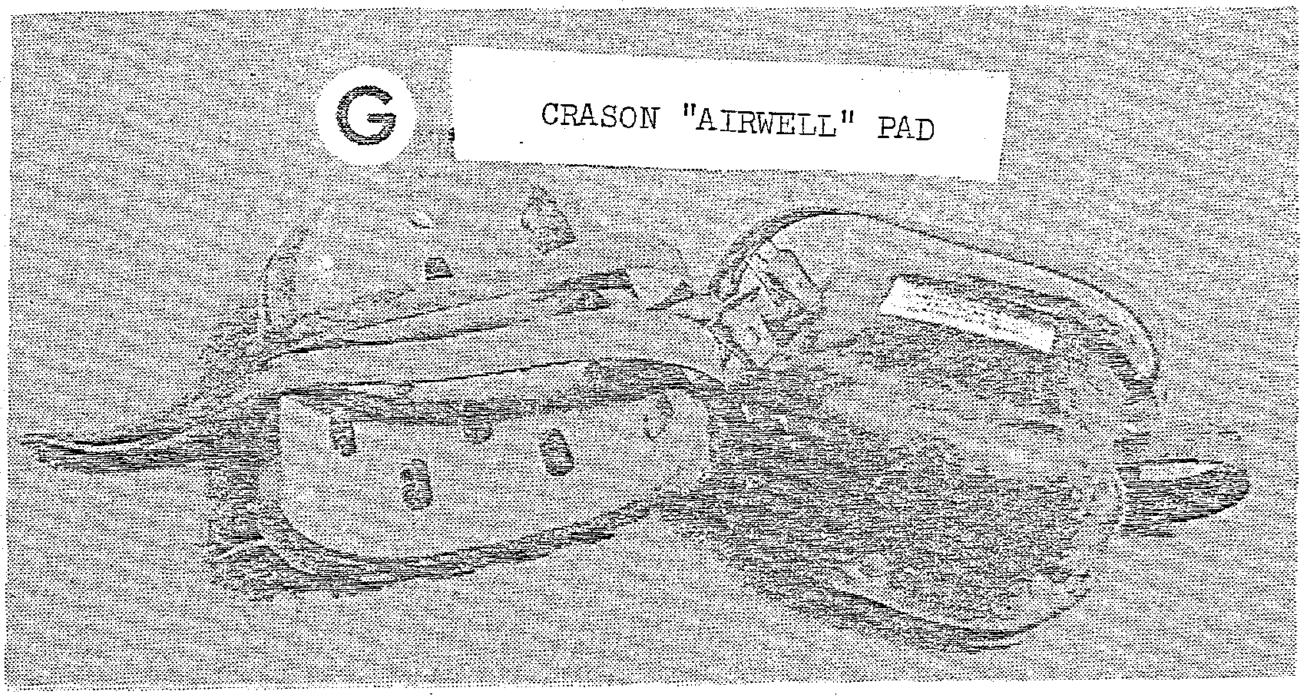


Figure 34. Crason "Airwell" pad. British made. Has ½" thick ventilated sponge cushion, rubberized web straps.

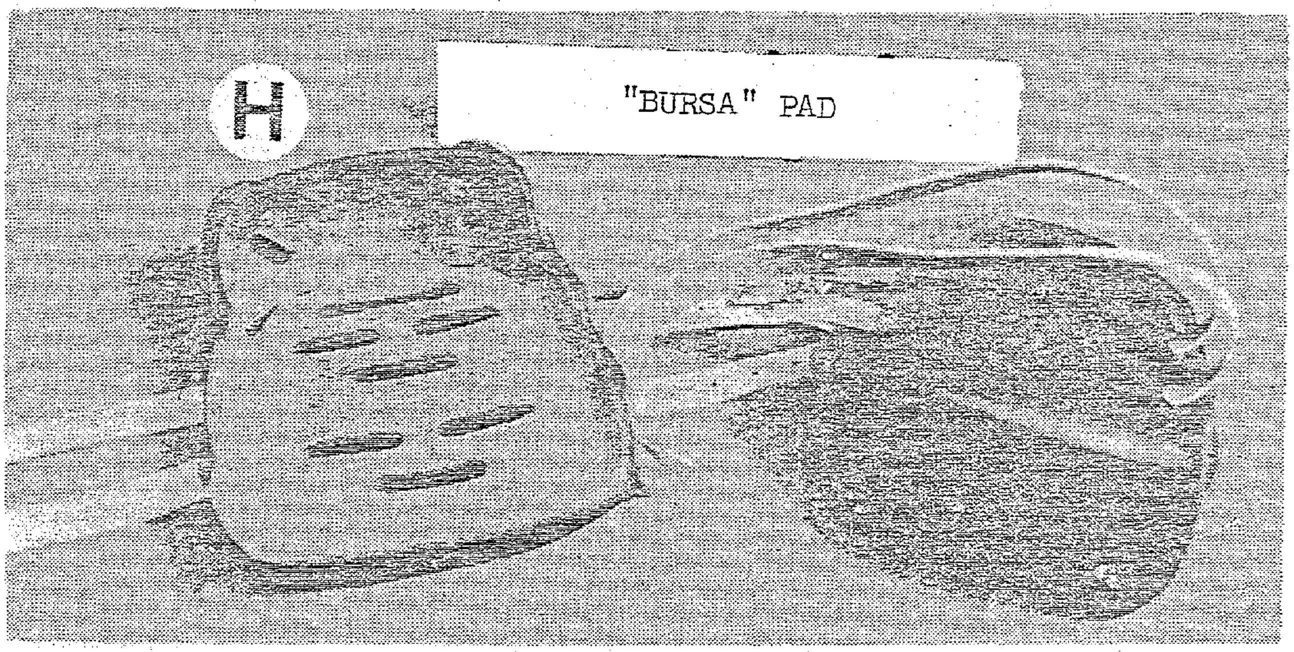


Figure 35. "Bursa" pad. British made. Has 3/4" ventilated sponge cushion, rubberized web straps.

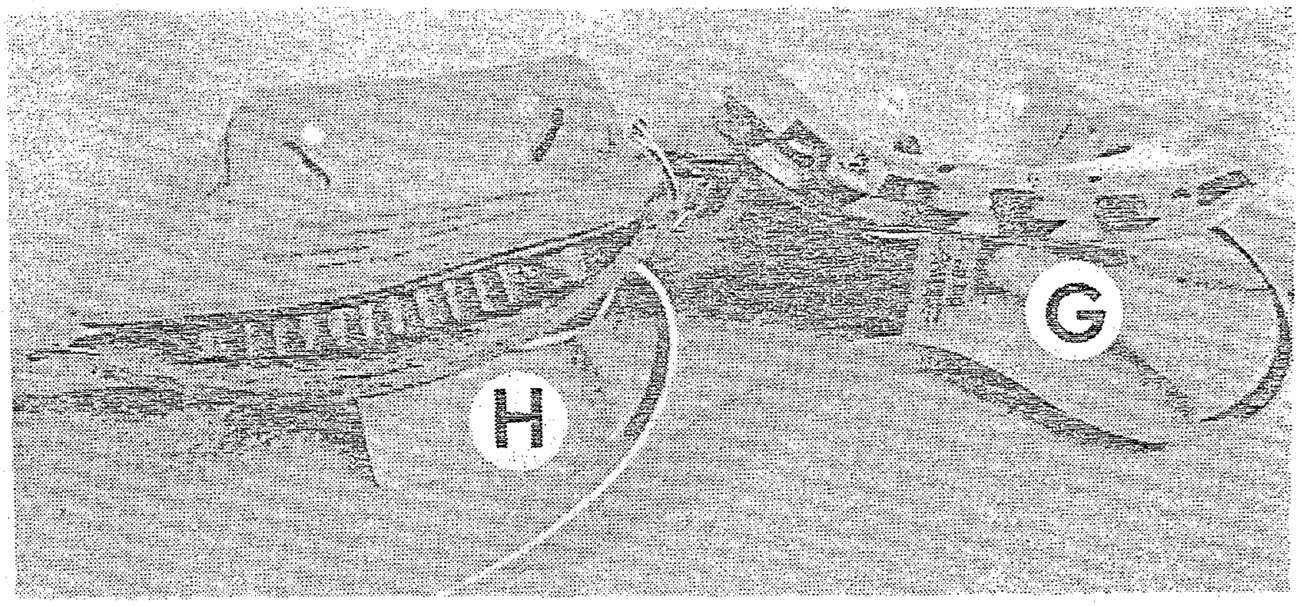


Figure 36. Showing the supports of the "Bursa" and "Airwell" pads' inner cushions. These were the only pads evaluated that come in two sizes. (H = "Bursa", G = "Airwell").

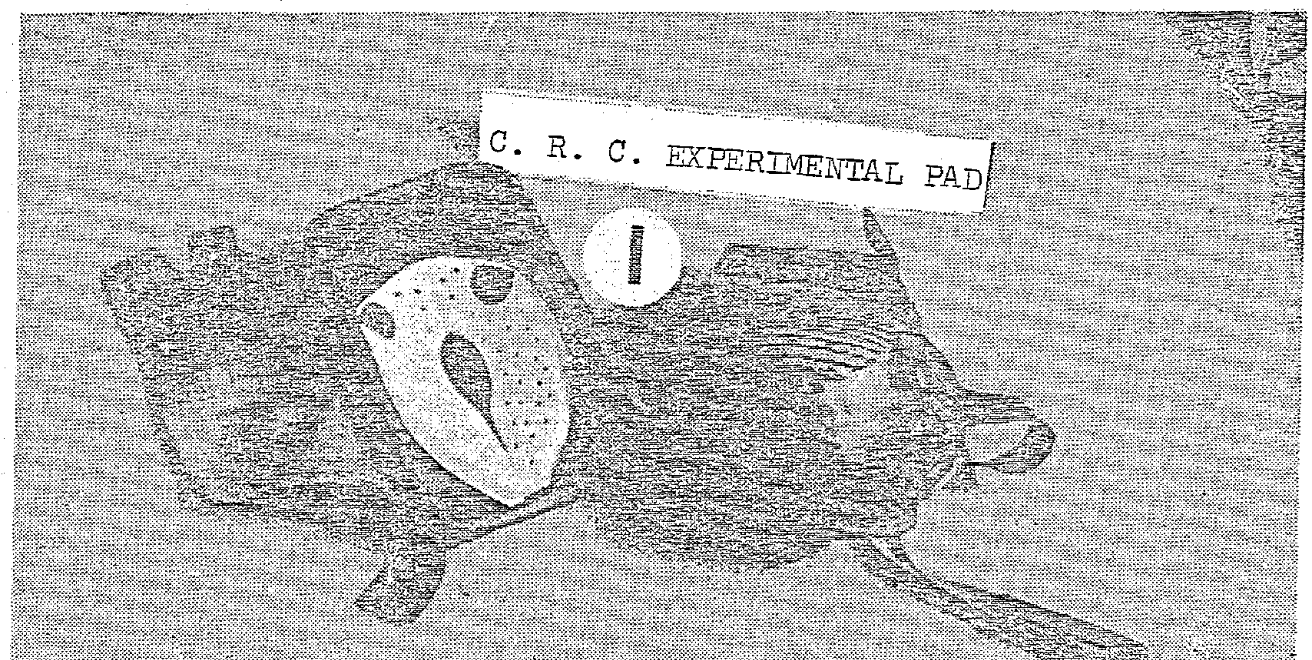


Figure 37. The C. R. C. experimental pad. Has a 3/4" sponge cushion, "U" shaped, ventilated; rubber straps.

RESULTS

The evaluation interview guide required the volunteers to rate each of the nine knee pads in four principal categories: the outer shell, the inner cushion, the fastening straps, and the overall assembly, meaning the entire knee pad. The men were asked to give numerical ratings on a scale from 0 to 10 to these features, taking into consideration comfort, ease of control or position retention, and convenience, meaning the ease of donning and doffing, and the degree to which the pads interfered with free movement. It is obvious that a certain amount of interrelation exists between these characteristics for each of the components, and that the adequacy or inadequacy of all components may well influence the performance of another. For example, a certain type of inner cushion may be comfortable to kneel on and to crawl on, but its height may cause it to buckle or turn to one side of the knee occasionally. This in turn could cause grit to enter the pad, affecting the comfort of the wearer. To prevent this from happening, the wearer might tighten the straps, which then could start binding or chafing, and the resultant evaluation could be a high rating for the cushion, and a low one for the straps.

The most important rating, then, is that of the whole knee pad assembly. The ratings for the individual components were used as additional data in the analysis of the results.

The nine pads were rated as shown in Tables 1 and 2.

Table 1. Averages of numerical ratings on a scale from 0 to 10 given to the performance of each overall knee pad.

Knee Pad Code Letter	Knee Pad Description	Average Rating for the Whole Knee Pad
A	Judsen	2.12
B	NMS "Knee-Eze"	6.35
C	"Rockmaster"	6.75
D	Nierhaus "Standard"	9.71
E	Nierhaus "Lightweight"	6.50
F	Nierhaus "Heavy Duty"	4.40
G	Crason "Airwell"	4.66
H	"Bursa"	3.15
I	Century Research Corporation Experimental	8.20

Or, in the order of preference:

D 1. Nierhaus "Standard"

I 2. Century Research Corporation Experimental

C 3. "Rockmaster"

B 4. N.M.S. "Knee-Eze"

E 5. Nierhaus "Lightweight"

G 6. Crason "Airwell"

F 7. Nierhaus "Heavy Duty"

H 8. "Bursa"

A 9. Judsen

ANALYSIS

Besides rating the overall performance of the knee pads they wore, the subjects also evaluated separate components of the pads, namely the inner cushion, the outer shell, and the fastening straps. In addition to rating these components on a numerical scale from 0 to 10, the subjects recorded their opinion of specific characteristics of each component, ranking it good or bad, and commenting on what should be done to improve those characteristics they found bad. The following table lists each knee pad and the average scores given to its separate components. As can be seen, in only one case (knee pad "D") are the ratings for each of the components very close. As seen in Table I, this particular pad had an overall rating consistent with its component ratings. All of the other pads tested varied somewhat in the ratings of their individual components. The lowest rating of the C. R. C. experimental pad received, (5th on a comparative scale), was for its fastening straps. This finding is discussed in a later chapter in this report, "Conclusions and Recommendations."

Table 2. Averages of ratings given to separate components of the knee pads. Ratings were on a scale from 0 to 10.

Knee Pad Type	Component		
	Inner Cushion	Outer Shell	Fastening Strap
Judsen (A)	0.75	2.50	3.75
N. M. S. "Knee-Eze " (B)	6.85	5.85	5.71
"Rockmaster" (C)	5.75	5.0	8.50
Nierhaus Std. (D)	9.57	9.71	9.42
Nierhaus Lt. Wt. (E)	6.25	4.75	8.25
Nierhaus H.D. (F)	5.60	3.60	7.80
Crason "Airwell" (G)	3.44	3.22	4.88
"Bursa" (H)	2.60	3.15	3.55
Century Research Corporation Experimental (I)	8.40	8.20	7.60

Inner Cushion Ratings

The firmness of the inner cushions tested ranged from medium thru medium-firm to firm, where a pressure of 5-9 PSI which causes the material to deflect 25% is considered medium, 9-13 PSI is called medium-firm, and 13-17 PSI, firm. There is an obvious interrelation between the firmness and the thickness of an effective inner cushion; the softer the cushion, the thicker it needs to be to provide protection against shock and uneven pressure distribution. The Century Research Corporation experimental pads had 3/4 inch-thick cushions in them that were in the 13-17 PSI or "firm" range. 80% of the subjects rated the firmness of the cushion "just right", and 20% felt that it should be softer; as for thickness, 80% rated it "just right", and 20% thought it should be thicker. It appears that when an inner cushion is rated inadequate, there is a wide variety of opinions as to whether the inadequacy is due to lack of thickness or to lack of firmness. In the case of one particular pair of knee pads tested in this last evaluation, all subjects agreed that the inner cushion of this particular type of pads was inadequate. All agreed that the inner cushion should be thicker. But when asked whether the cushion should be firmer, softer, or was just right, 25% thought it should be softer, 25% thought it was just right, and 50% thought it should be firmer.
When asked what the condition of their knees was after testing the Century Research Corporation pad, 40% answered "sore",

and 60% "in good shape". All had reported their knees "in good shape" before testing that particular pad. The "U" configuration of the experimental inner cushion tends to "squirm" under the knee if the cushion is too soft. This normally leads to blisters. When asked whether the cushion of the experimental pad tended to cause blisters, 100% answered "no." By contrast, the reports on the softest cushion tested showed that 75% thought it had a tendency to cause blisters.

To the question whether the experimental pads tended to cause more sweating than the pads the subjects normally wear, or less, 80% answered "about the same", and 20%, "less". This is obviously to some extent a function of the outer shell as well as of the inner cushion, but since the knee is mostly in direct contact with the inner cushion and since most cushions are made of heat-insulating materials such as sponge or foam, the inner cushion is considered the principal factor in thermal comfort.

Likewise, the question regarding entry of grit and/or rocks into the pads is also a function of the outer shell as well as the inner cushion; some cushions tend to retain foreign matter allowing it to build up, whereas the shape of others encourage such matter to drop out. The subjects were asked to compare the entry of grit and/or rocks with that of their usual pads; 80% answered that about the same amount entered the pads, and 20% found that the amount entering the experimental pads was less. The average rating given the inner cushion of the experimental pads was 8.40, on a scale of 0 to 10.

Outer Shell Ratings

Questions regarding the outer shell concerned the dimensions, the shape, and the effectiveness of the treads. Reporting on the experimental pads, all subjects answered the questions regarding overall length, overall width, and height of the sides with "just right"; however regarding the fit of the outer shell, 20% checked the answer "too snug, causing irritation"; none thought it too open, and 80% thought it just right. Regarding the usefulness of treads on the bottoms of knee pads, 40% of the subjects thought they have merit, and 60% think they don't. Of those who thought treads have some merit, 100% approved of the depth of the treads on the experimental pads. The average numerical rating for the outer shell of the experimental pads was 8.20, on a scale of 0 to 10.

The Fastening Straps

Of all the knee pads tested, one pair had leather straps, one pair had straps made of webbing, two pairs had rubberized web straps, and the rest had either woven elastic or rubber straps. The highest average rating given to the straps that were not elastic or rubber, was 5.71, on a scale from 0 to 10.

For the elastic straps this figure was 8.50, and for the various types of knee pads with rubber straps, the lowest average score was 7.60; the highest was 9.71, indicating a clear preference for stretchable material for fastening straps.

Reporting on the straps for the experimental pads, 40% of the subjects found that the straps chafed the back of their knees while walking; 40% found the straps chafed while crawling; 60% reported that the straps did bind (cut the blood circulation).

As to position retention, 80% thought the straps did adequately hold the pads both while walking and while crawling, 20% thought they did not. The degree of adjustment was found satisfactory by 80%, and 80% found the straps caused no objectionable sweating. The average rating given to the straps for the experimental pads was 7.60 out of a possible 10. By contrast, reporting on the standard Nierhaus pads, the answers to all questions regarding the straps were 100% favorable with the exception of the question concerning the degree of adjustment, where 16% of the answers were unfavorable. The average numerical rating given to the straps on those particular pads was 9.42 out of a possible 10.

The Complete Knee Pad Assembly

Aside from 20% of the subjects who thought the overall size of the experimental pads was too large, the main comment was concerning the weight of the pads; 80% found them to be too heavy. This had been expected, however. The pads weighed slightly over 1½ lbs. each, as compared to slightly over 1 lb. for the N. M. S. "Knee-Eze" pad, slightly under 1 lb. for the Standard Nierhaus pad, and about 10 oz. for the Judsen pad. The only other pad tested that weighted almost as much was the heavy duty Nierhaus pad, which weighed slightly under 1½ lbs. Reporting on this knee pad, 80% of the subjects found it too large, and 100% found it too heavy. It is interesting to note here that 80% found the experimental pad too heavy, yet it weighed about 2 oz. more than the Nierhaus heavy duty pad. The theory here is that the bulkier looking Nierhaus pad appeared to weigh more than it actually did. In spite of its excessive weight, the average score for the experimental knee pad (the entire knee pad assembly) was 8.2 on a scale from 0 to 10, the second highest score of all the knee pads tested.

The reason for the excessive weight of the experimental pads is the material that went into the outer shell. It is a commercially available two-component urethane consisting of a liquid resin and a liquid curing agent which can be mixed, molded and cured at room temperature and requires no pressure. This makes it particularly suitable for prototype experimentation. For quantity production, a considerably lighter but equally tough material would be used.

CONCLUSIONS AND RECOMMENDATIONS

The principal objective of the development and evaluation program described in this report has been the reduction of pre-patellar bursitis among low coal mine workers. It has been our theory throughout that the answer to the problem lay with the inner cushion of the knee pads these workers were using, the part of the pad supporting the wearer's knee during use. Once the basic configuration of that inner cushion had been agreed on, it has been our method to design and develop the rest of the knee pad around this cushion, construct the pad "from the knee out" as it were.

Development now became a matter of making the whole knee pad assembly acceptable to the wearers, in other words, design an outer shell that would "work" with the prescribed cushion without letting foreign matter enter, and without irritating the wearer's knees. What we aimed for was an adequately protective yet unobtrusive knee pad.

From the results of the evaluation we conclude that we have succeeded, to a degree, to make an experimental pad acceptable to the user. The concrete product then, at this point, is a prototype knee pad with an inner cushion unlike any other, that was formed specifically to prevent or at least reduce pre-patellar bursitis, but has not yet been proven on that score; and which after considerable research as well as trial and error, now compares favorably in comfort with the majority of commercially available knee pads.

The proof of the effectiveness of the inner cushion in preventing pre-patellar bursitis will require large scale and fairly long-range testing.

However, before the experimental pad is produced in quantity to conduct such testing, certain modifications should be made based on the foregoing analysis. The knee pads submitted along with this report are of the same model as that tested during the last evaluation described in this report. The recommended modifications that follow are based on this model, its component materials, dimensions and configuration.

Material

The recommended material for the outer shell is SBR, a styrene-butadiene elastomer, a material considerably lighter than the urethane used in the prototypes, but with approximately the same flexibility, tear and abrasion resistance. It is also less expensive than urethane. It can be injection molded. The recommended hardness for the outer shell is in the 65-70 durometer range. For the inner cushion it is recommended that natural rubber, open pore sponge be used, self-skinning, and of a density necessary to give 12-14 PSI compression deflection (to 25% deflection). If natural rubber sponge is considered prohibitive in cost, a natural rubber-SBR compound sponge can be used, with a slight sacrifice in long-duration resiliency.

The recommended fastening strap material is neoprene, as is the material for the fastening buttons. Recommended hardness for the buttons is 60 durometer.

Dimensions

The variety of knee sizes observed during the course of this project has led us to the conclusion that a knee pad such as the Century Research Corporation experimental pad, with its semi-rigid outer shell, should be available in two sizes.

Considering the submitted pads as the smaller or medium size, a large size pad would be made by adding $\frac{1}{2}$ inch to the overall width of the outer shell and to that of the inner cushion. The length of outer shell and inner cushion would remain the same for both sizes. In the case of the inner cushion, $\frac{1}{4}$ inch in width would be added to each side of the cushion without altering the center section; but the distance between the two holes for the fastening buttons would be increased by $\frac{1}{2}$ inch.

Configuration

For the outer shell, a 0.05" reduction in wall thickness for the sides and front is recommended, and a 0.10" reduction for the bottom. Along with the change to SBR for the outer shell material, this should result in a significant weight reduction.

The inner cushion configuration recommended is illustrated in Figure 38. It differs from the prototype cushions submitted in that it has an added web connecting the two legs of the horseshoe shape, reducing the tendency for the cushion to squirm under the wearer's knee when crawling. The web also slightly increases the bearing area of the cushion while still avoiding pressure concentration on the tibiar tubercle.

The fastening straps on the knee pads submitted are of the configuration tested in the last evaluation. Considerable experimentation with wide straps, both curved and straight, with and without auxiliary narrower straps, has yielded the desired result. Recommendation is a return to the conventional system using two narrow straps.

Evaluation Scenes

Figures 39 and 40 show the experimental pads in use.

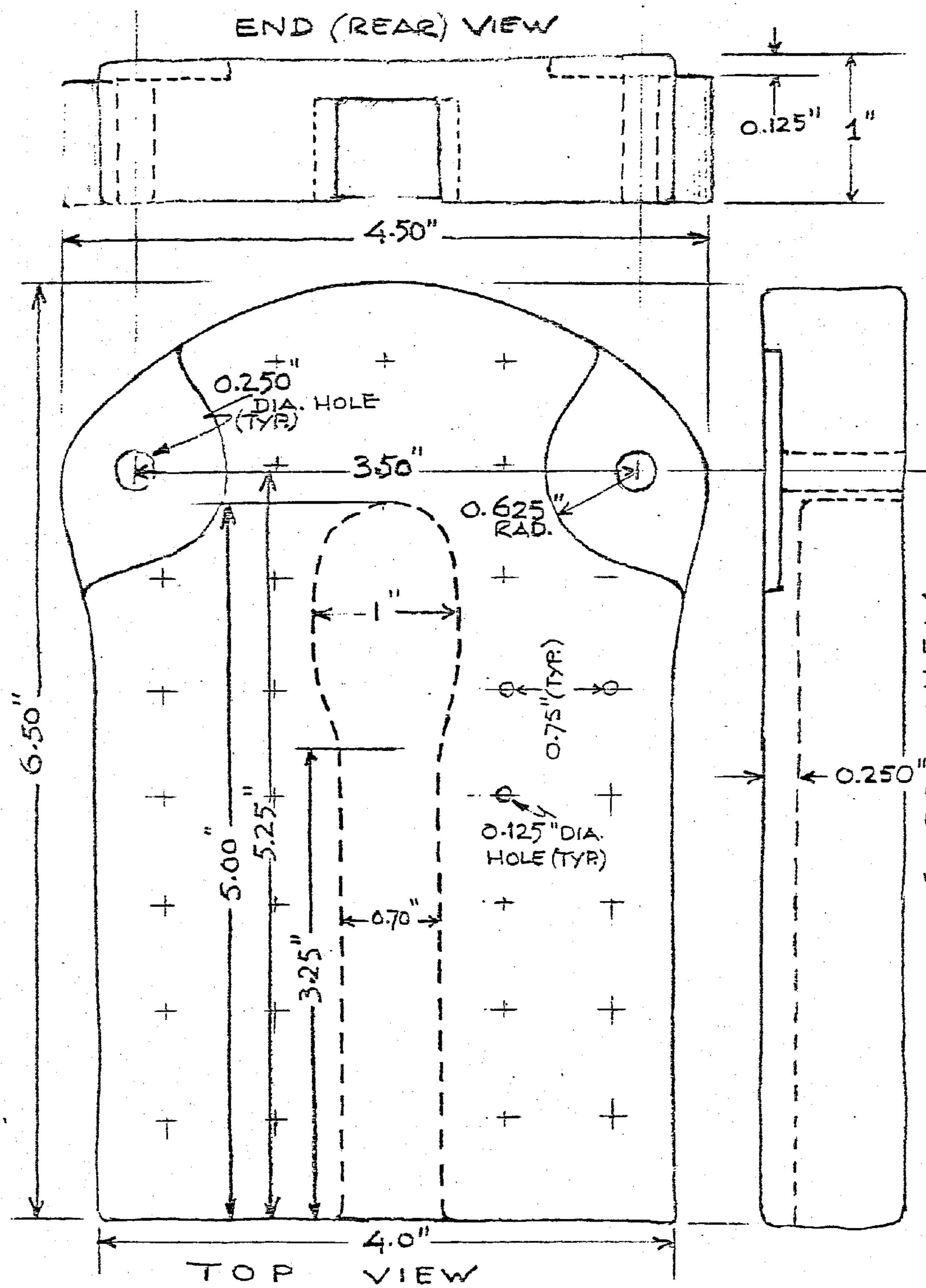


Figure 38. Dimensional sketch of the recommended inner cushion.

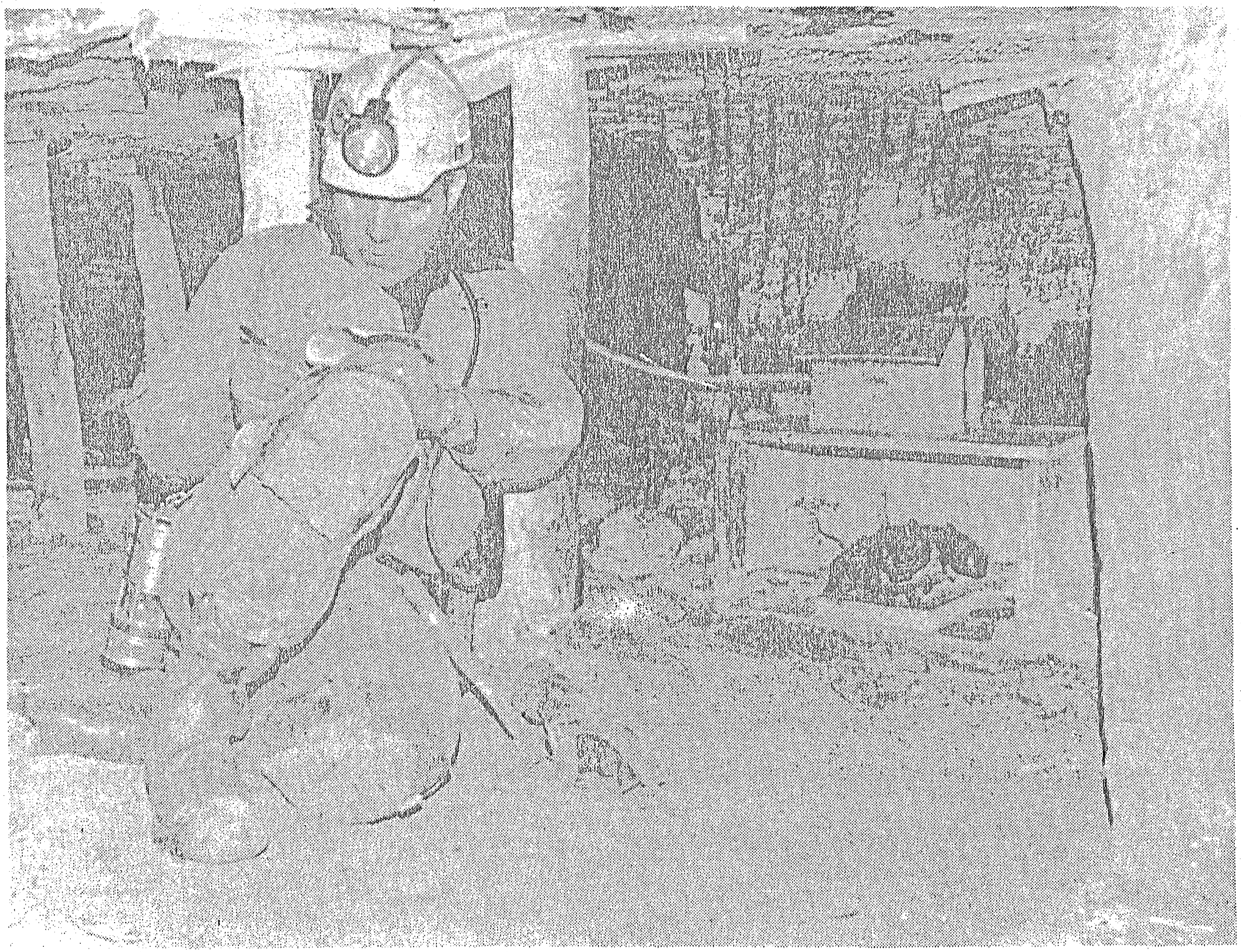


Figure 39. In-mine evaluation of the latest Century Research Corporation experimental pad.

Figure 40. In-mine evaluation of the latest Century Research Corporation experimental pad.

Future Development

Apart from one attempt to fasten knee pads to coverall pants, all development in this program has been kept within parameters determined among others by the requirement that any knee protective device resulting from this program would be usable in conjunction with work clothes and other personal equipment available today.

In the course of our research it has become quite evident to us that in order to provide the coal miner with significantly improved personal work and safety equipment, the approach should be a coordinated one. The question of how to attach knee pads securely to the legs without causing irritation could likely be solved by having an integrated pants legs-knee pads system with the pads built into the pants legs or attached to them. But in order to use this approach successfully, the pants would have to be of a more advanced design than those presently used; possibly somewhat like skiers stretch pants, but of a more heavy duty material. This would not only allow knee pads to be attached to the pants, it would eliminate the irritation in the back of the knees caused by bunching up of excess material, and it would eliminate as well the need for pant cuff straps currently prescribed to prevent wide, floppy coverall or work pants trouser legs from getting caught in moving machinery.

Similarly, there is an evident need for modernization and integration of other personal equipment, a need for design with a specific environment, such as low coal, in mind; a self-rescuer or a headlight battery that is acceptable for the man who stands up and walks may not be the ultimate in convenience for a low coal worker who has to crawl, often through tight spaces. Even streamlining of some of the bulkier equipment would be helpful there if volume and weight could not be reduced.

It is our recommendation that until more advanced personal equipment becomes generally available, Federal and state employees such as U. S. Bureau of Mines inspectors and State mine inspectors be issued knee pads of their preference, or that at least two types of the most popular knee pads be issued. It has been our observation that a large percentage of the Federal inspectors bought their own knee pads rather than use those issued. Incompatible knee pads, like ill-fitting boots are not only uncomfortable, they cause temporary disability. A wider selection of government-issued knee pads, based on the preference of the majority of users, would be an important improvement.

At a time when coal mining is again increasing in importance to the National economy, the development of personal equipment for the mine worker that is up-to-date with the present technological state of the art would seem to be a worthwhile effort.

APPENDICES

Appendix A: Interview Guide--1st
December, 1972

Appendix B: Interview Guide--2nd
3/73

and

Use Testing
3/73

Appendix C: Rating Form
1/74

December, 1972

INTERVIEW GUIDE:

KNEE PAD EVALUATION PROJECT

We are doing a study regarding the use of protective knee pads by men in coal mining. The information will help us to develop knee pads that provide better protection and are more comfortable than those now in use. (Our company is sponsored in this research program by the National Institute for Occupational Safety and Health, U. S. Department of Health, Education and Welfare.) I will ask you some questions regarding your work and knee protection.

Interviewer's initials______ Date_________ Facility name or

I. Interviewee: USBM employee____ Age_______ Height_____________
Weight__________ Inspector __________ Other (specify______________
How long in job requiring knee pads (yrs)_________

II. Mining Co. employee____ Age_______ Height________ Weight_______
Job name_____________ How long in job requiring knee pads(yrs)_____

(Optional) (Name_________________________________ Phone___________
(Address____

****

1. Range of height of ceiling worked under: __________to______inches.
2. Average height most frequently worked under:______________inches.
3. How many hours a day do you spend kneeling?_____________hours.
4. How many hours a day spent crawling?__________ hours.
5. Floor surface moist: most of time_____ sometimes_____ never_______
Wet, w/standing water: most of time_____ sometimes____ never_______
6. Chemicals on ground: oil_____ gas_______ other_________________
7. Protruding nails, splinters, sharp objects: frequently___rarely____

8. Have you ever had a knee injury during work? Yes___ No___
9. What type? Fracture___ Dislocation___ Laceration___ Puncture______
Torn ligament(s)____ Severe blow___ Other_______________________
10. Were you wearing knee pads at the time? Yes____ No_____
11. Have you ever had other knee problems such as bursitis_____
arthritis___ or just plain sore or stiff knees___? Other_________
12. Was this bothersome all the time____ during work____ after work__

13. PRESENTLY USED PADS: Type: NMS (red)___ Rockmaster____
MSA (Judson, black)_____ Nierhaus____ Other_____________________
14. Cost: $_________ How long do they last?____________months.
15. When bought?_________________ Where bought?____________________
Wear them? always________ most times________ rarely_____________
16. If type has two straps, wear them crossed_______ parallel_______
17. What do you like most about these pads?___________________________
____

18. What do you like least about them?_________________________________

'. Have you "customized" or altered these pads? Yes______ No_________
If so, how?____

____

). Number of layers of clothes worn under or over knee pads?
Summer: under______ over_____ Winter: under______ over_______

****

.. NEW PROTOTYPE PADS: Circle type pads you have tested: A B C D E

(We'll try to put your opinion of the pads you tested into three categories: inner cushion, outer shell, and fastening straps.)

a. The Inner Cushion: Excellent____ Good____ Fair_____ Poor________
b. Should be firmer_____ Softer______ Is just right_______
c. Should be thicker____ Thinner______ Is just right_______
d. Tendency to roll out of it? Yes______ No_______
e. Did it gradually flatten out? Yes______ No_______
f. Tendency for cushion to slip out of outer shell? Yes_____ No______
g. Do you think the shape of the cushion is good? Yes_____ No_______
h. If no, how would you change it?_________________________

____

i. Is outer skin of cushion tough enough? Yes______ No______
j. Should it be smoother______ or less slippery?_________
k. Did you experience less sweating than with your usual pads or more?
Less_____ more_______ About same_______
l. Does the inner cushion tend to retain grit and/or rocks that enter____, does it shed them_______, or none got in________?
m. Other comments concerning inner cushion:__________________

____

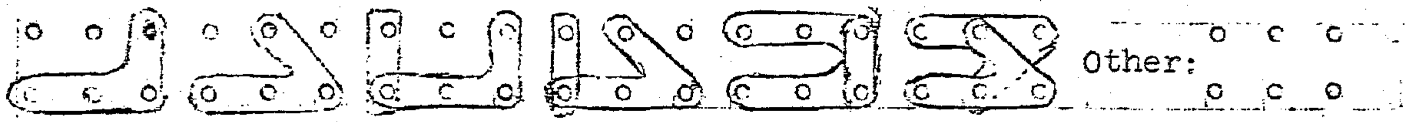
a. Outer Shell: Excellent_______ Good________ Fair________ Poor__________
b. Should be Wider____ Narrower_____ Is just right_______
c. Should be longer______ shorter______ Is just right________
d. Sides should be Higher______ Lower________
e. Treads are: too deep_______, right depth________, should be different pattern_______ Comment ___________________________; tread should extend all the way up front__________, should extend all the way up sides_______.
f. Material of outer shell should be more rigid_____, less rigid______, is just right_______.
g. Shape of outer shell is: just right_____; too open, collects rocks and grit_____; too snug, chafes or causes pressure points_______ (specify)____

Other comments concerning outer shell:______________________

____

54

24a. Fastening Straps: Excellent____ Good____ Fair____ Poor________
24b. What strap combination did you use: (circle one)



24c. Did straps chafe while walking? Yes____ No______
while crawling? Yes____ No______
24d. Did straps bind (tend to cut circulation)? Yes____ No______
Did straps hold pads in position while walking? Yes______ No______
while crawling? Yes______ No______
24e. Did they cause objectionable sweating? Yes______ No______
24f. Were they adjustable enough? Yes______ No______
24g. Other comments concerning fastening straps:____________________

____

(Now we would like your opinion on the overall pads, inner cushion, outer shell, and fastening straps combined.)

5. Size: Too bulky____ Just right______
6. Weight: Too heavy______ Just right______

7. Compared to the pads you normally use, the ones that you just tested are: Much better______; Somewhat better___; about the same_____; Not as good______; much worse_____.

8. If you were to design your own pads, what improvements would you design into them, as compared to the experimental type you have been wearing? Comfort: Make inside softer___ Make inside more form-fitting____ Make cooler to wear____ Make drier to wear_____ Make warmer to wear on cold floor____ Make attachment less chafing____ Make pads stay in place better____
Other____

Re shell: Make outer shell more resistant against impact_____ Against cuts & punctures____ Make them longer to protect part of shin as well____ Wrap around more to protect sides of knees_____
Other____

9. If knee pads were more comfortable, gave better protection, and lasted longer than those you now use, how much would you be willing to pay for a pair: $______ Explain________________

0. Overall Design Features: Make more resistant against abrasion____ Improve bond between inner cushion and outer shell____ Build pads into trouser legs____ Make them easier to adjust____ Make inner cushion and outer shell to be worn separately____ Make in a bright color________ (preferred color________________)
Make to last longer____________ (how long____________________)
Other overall design suggestions____________________________

1. Additional comments:______________________________________

____

CENTURY RESEARCH CORPORATION, 4113 Lee Highway, Arlington, Va.22207

INTERVIEW GUIDE FOR KNEE PAD EVALUATION

We are in the process of developing a new protective knee pad for people who have to kneel and crawl a great deal in their work. This form is to record your opinions about the pads. The information you give us will help us in the further improvement of the pads you have tested today. Your answers will be kept confidential by Century Research Corporation. Our company is sponsored in this research program by the National Institute for Occupational Safety and Health, U. S. Department of Health, Education and Welfare. I will ask you some questions regarding your work and knee protection.

Date ____________ Code ____________

Name of mine where used today ____________

Address ____________ Phone ____________

Superintendent of this mine ____________

Your name ____________ Miner ____ Inspector ____

Address ____________ Home phone ____________

Age ______ Height ____ ' ____ " Weight ________ lbs

* * * * * * *

1. How many years in job requiring knee pads ________?
2. How much time since you did last low coal work?
   1 week or less ________; ________ weeks; ________ months.
3. How many hours a day do you spend kneeling? ________ hours.
4. How many hours a day spent crawling? ______ hours
5. Have you ever had a knee injury during work? Yes _____ No _____
6. What type? Fracture ___ dislocation ___ laceration ___ puncture ___
   torn ligament(s) ___ severe blow ___ Other ____________
7. Were you wearing knee pads at the time? Yes ___ no ___
8. Have you ever had other knee problems such as bursitis ___
   arthritis ___ or just plain sore or stiff knees ___? Other ________
9. Was this bothersome all the time ___ during work ___ after work ___?

PRESENTLY USED PADS

10. Type: NMS (red) ___ Rockmaster ___ MSA (Judson, black) ___
    Nierhaus (German) ___ Other ____________
11. How long do they last? ____________ months
12. Wear them? Always ________ most times ________ rarely ________
13. If type has two straps, wear them crossed ______ parallel ______?
14. What do you like most about these pads? ____________

    ____

15. What do you like least about them? ____________

16. Have you "customized" or altered these pads? Yes____ No________
If so, how?____

17. Number of layers of clothes worn under or over knee pads?
Summer: under_______ over Winter: under_______ over_______

* * * * * * *

18. NEW PROTOTYPE PADS:

(We'll try to put your opinion of the pads you tested into three categories: inner cushion, outer shell, and fastening method.)

INNER CUSHION

19a. Should be firmer_______ softer_______ just right________
19b. Should be thicker______ thinner_______ just right________
19c. Tendency to roll out of it? Yes_______ no_________
19d. Did it gradually flatten out? Yes______ no_________
19e. Tendency for cushion to slip out of outer shell? Yes___ no_____
19f. Do you think the shape of the cushion is good? Yes_____ no_____
19g. If no, how would you change it?______________________________

19h. Is outer skin of cushion tough enough? Yes_____ no_______
19i. Should it be smoother_____ or less slippery?___________
19j. Did you experience less sweating than with your usual pads or more? Less______ more________ about the same________
19k. Does the inner cushion tend to retain grit and/or rocks that enter_____ does it shed them______ or none got in______?
19l. Other comments concerning inner cushion?______________________

19m. Overall opinion of inner cushion Excellent______ good________
fair_______ poor______

OUTER SHELL

20a. Should be wider______ narrower______ just right________.
20b. Should be longer______ shorter______ just right________
20c. Sides should be higher______ lower______ just right________
20d. Treads are: too deep______ right depth_____ should be different pattern_____. What?________________________
Tread should extend all the way up front_____ should extend all the way up sides_______.
20e. Material of outer shell should be more rigid_____ less rigid_____ Seems OK_______
20f. Shape of outer shell is OK____ too open (collects rocks and grit)____ too snug (chafes or causes pressure points)_______
Specify____
Flat sole of outer shell is good feature____ or bad feature____
Comment____

20g. Other comments concerning outer shell: ______________________

____

20h. Overall opinion of outer shell: Excellent____ good_____ fair_____ poor_____

FASTENING METHOD: ZIPPER

21a. From the point of view of comfort, did the use of a zipper instead of a front strap satisfy you? Yes_____ no_____
If not, what was wrong with it? ______________________

21b. From a practical point of view, do you think this fastening method has merit? Yes____ no_____

21c. If you could buy knee pads using this fastening method (perhaps improved using your suggestions) would you buy them rather than pads using conventional straps? Yes____ no______
If not, why? ______________________

____

21d. Overall opinion of zipper fastening method: Excellent__________ good______ fair______ poor______

FASTENING METHOD: STRAPS

21f. Did straps chafe while walking? Yes______ no______
while crawling? Yes______ no______

21g. Did straps bind (tend to cut circulation)? Yes_____ no________
Did straps hold pads in position while walking? Yes____ no___
while crawling? Yes____ no___

21h. Did they cause objectionable sweating? Yes____ no_____

21i. Were they adjustable enough? Yes____ no_____

21j. Overall opinion of fastening straps: Excellent_____ good_____ fair_____ poor______

(Now we would like your opinion on the whole pad--inner cushion, outer shell, and fastening method combined.)

22. Size: Too bulky_______ OK______

23. Weight Too heavy_______ OK_______

24. Compared to the pads you normally use, the ones that you just tested are: Much better_____ somewhat better_____ about the same_____ not as good_____ much worse______

25. (Check where applicable) If you were to design your own pads, what improvements would you design into them as compared to the experimental type you have been wearing?
Comfort: Make the inside softer____ make inside more form-fitting_____ make cooler to wear_____ make drier to wear_____ make attachment less chafing____ make pads stay in place better_____
Other______________________________________

Regarding the shell: Make outer shell more resistant against impact_____ against cuts and punctures_____ make them longer to protect part of shin as well_____ wrap around more to protect sides of knees______
Other____

26. If a knee pad were commercially available that would outlast all others, was satisfactory as far as comfort was concerned, kept the wearer's knees dry, and gave the wearer good protection all around, what would you say a man working in low coal would be willing to pay for a pair? $5-10______ $11-15______ $16-20_____ $21-25______ Other $______

Comment____

27. What do you think about these possible design features:

Improve bond between inner cushion and outer shell___________
Build pads into trouser legs_________________________________
Make them easier to adjust___________________________________
Preferred color____
Make inner cushion and outer shell to be worn separately______
Other overall design suggestions_____________________________

____

28. Additional history of any knee problems______________________

____

29. Additional comments:____

____

____

____

____

____

USE-TESTING OF EXPERIMENTAL KNEE PAD

(Please fill out at end of each day of use)

Name________________________________ Date__________

INNER CUSHION: Getting broken in, more comfortable than previously________ Unchanged_________ Flattening out___________

Showing rips and cuts________ Coming apart_________________

Other____

OUTER SHELL: No apparent change_______

Showing wear________ Degree: Slight_______
Average_______
Extreme_______

Coming apart at seams____

Button holes in shell are tearing out_____ Front "apron" is coming loose______ Aluminum plate is coming loose ___________

Other____

FASTENING:

A. Zippers: No change______ Zipper coming off coveralls_______

Zipper coming off rubber apron______

Zipper halves pulling apart______

Other____

B. Straps: No change________

Straps breaking______ Where? (mark)

Straps getting slack, losing elasticity________

Straps pulling off buttons______ Where? (mark)

Buttons breaking off______

Other____

Overall impression of pads compared to previous day:

Like better_____ About same______ Like less__________

Mine where used____________________________ Number of hours kneeling or crawling______________ [COMMENTS ON BACK]

RATING FORM

KNEE PAD EVALUATION PROJECT

Century Research Corporation is doing a study regarding the use of protective knee pads by men in coal mining. The information will help us to develop knee pads that provide better protection and are more comfortable than those now in use. (Our company is sponsored in this research program by the National Institute for Occupational Safety and Health, U. S. Department of Health, Education and Welfare.)

You will be asked to wear a different type of knee pads every day for nine days. Some of them will be familiar to you, others will be new to you. At the end of each work day you are requested to evaluate the knee pads you wore that day by filling out the attached form. Do not discuss the pads with other inspectors; we need your opinion independent of others. Please leave the completed form in George Vargo's office. Thank you for your cooperation.

Date ________________1974

Name of mine where today's test took place ________________________

Name ____

(Optional) Address ______________________________ Home Phone ____________

Age __________ Height ______________ Weight ________________

How long have you been using knee pads? __________yrs.

What type are the pads you usually wear? (Check one)

Thin, black "Judsen" pads ____
Red NMS pads ____
Rockmaster pads ____
German pads ____
Other (please give brand name ____
if you know it) ___________________________

****

1. Approximately how long did you wear the pads you tested today? ____hrs
2. Please divide that roughly into time spent kneeling stationary and time spent crawling. Kneeling, approx.________ hrs.
   Crawling, approx.________ hrs.
3. What is your estimate of the usual ceiling height in the mine you were in today? Approx. ________ inches.
4. Have you ever had knee problems such as bursitis____ arthritis____ or just plain sore or stiff knees______?

5. Has either one or both of your knees ever been operated on______ or drained______?

6. Before you put the pads on this morning, was either one or were both your knees: in good shape_____ stiff_____ sore_____ blistered_____ raw or tender in back of knee(s)_________? Other_______________

7. What is the condition of your knees now? In good shape______ Stiff____ Sore____ Blistered____ Raw or tender in back of knees____ Other_______________

8. How many layers of clothes did you wear under your pads today?____

NOTE BELOW: We'll try to put your opinion of the pads you tested today into three categories: Inside or inner cushion, outside or outer shell, and fastening straps.

Inner Cushion

9. Should be firmer____ softer____ is just right______.
10. Should be thicker_____ thinner_____ is just right______.
11. Did it gradually flatten out? Yes____ No____
12. Does it tend to cause blisters? Yes____ No____
13. Does it tend to slip out of the outer shell? Yes____ No____
14. Did you experience more sweating inside the pads than you do with your usual pads? More____ About the same____ Less_____
15. Did you get more grit and/or rocks inside the cushion than usual? More____ About the same____ Less_____
16. Any further comments about the inside or inner cushion?___________

17. On a scale from 0 to 10, where 0 is very poor and 10 is outstanding, what rating would you give the inner cushion (or in the case of the red pads, the inside)? Please check(✓) along line.

0 1 2 3 4 5 6 7 8 9 10

VERY POOR — OUT-STANDING

The Outer Shell

18. Should be wider____ narrower____ is just right____
19. Should be longer____ shorter____ is just right____
20. Sides should be higher____ lower____ are about right____
21. Some pads have deeper treads than others, some have none; in your opinion, are treads useful? Yes____ No____
If yes, were the treads on the pads you tested today not deep enough (or none at all)____ too deep____ or about right_____
22. Regarding the fit of the outer shell, was it too snug, causing irritation____ just about right____ too open, allowing grit and/or rocks to enter____?
23. Any further comments about the outer shell or outside?___________

24. Please rate the outer shell or the outside design of the pads you were evaluating today on a 0 to 10 scale:

0 1 2 3 4 5 6 7 8 9 10

VERY — OUT-

The Fastening Straps

25. In case of double, straight straps, did you wear them parallel___ crossed___?
26. Did straps chafe while walking? Yes____ No____
while crawling? Yes____ NO____
27. Did they bind (tend to cut circulation)? Yes____ No____
28. Did they hold the pads in position while walking? Yes____ No____
while crawling? Yes____ No____
29. Were they adjustable enough? Yes____ No____
30. Did they cause objectionable sweating? Yes____ No____
31. Other comments about straps: ____________________

____

32. Please rate the strap on the pads you were evaluating today on a 0 to 10 scale:

0	1	2	3	4	5	6	7	8	9	10
VERY POOR										OUT-STANDING

The Entire Kneepad

33. Size: Too small____ Too large____ Just right____
Weight: Too heavy____ OK____
Any further comments regarding the entire knee pad?

____

____

____

34. Considering all the above features, what overall rating (between 0 and 10) would you give the pads you evaluated today?

0	1	2	3	4	5	6	7	8	9	10
VERY POOR										OUT-STANDING

35. Any other comments? (Such as design suggestions, or comments about the evaluation itself, for instance.)

____

____

____