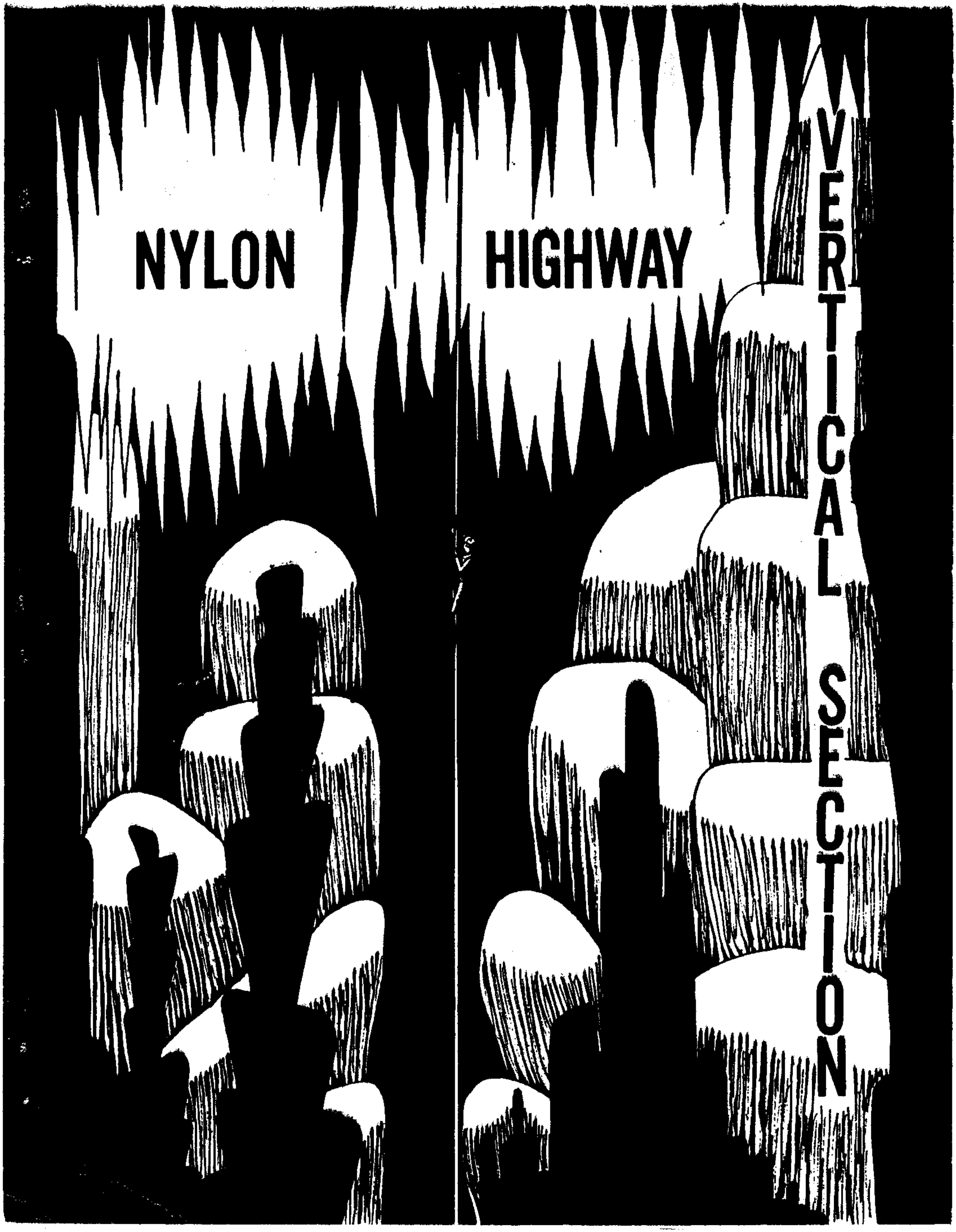
NYLON HIGHWAY
VERTICAL SECTION

NYLON HIGHWAY

NO. 1

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We are also proud to annouce these additional new members:

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Bruce Herr
Robert Nadich
Tom Ramsey
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HOW TO SUBMIT MATERIAL"

In able to have an authoritarian vertical oriented newsletter we need good material on the subject of vertical travel and related topics. These articles can be reprints from other newsletters or original material. Letters to the editor are encouraged but the editor claims the right to censor or alter any article in a way as to fit the publication without changing the intent of the article. We do request that new material be supported with tests and field usage records. Let's please stay away from politics. All pictures are requested to be black and white pen and ink drawings. The editor is able to redraw upon request any pictures of explanation that are unclear. Please submit all material to Bruce W. Smith, 1197 Spaulding Street, Stauton, Va. 24401

NYLON HIGHWAY

The NYLON HIGHWAY is an official publication of the Vertical Section of the National Speleological Society; published at least twice, but not more than four times a year by the annually elected editor. Subscriptions are $2.50 a year while membership dues are $2.00 a year. To enstate oneself as a member of the Vertical Section one will need the enorsement of two charter members or two non charter members who have been members for two or more years.

COVER

The cover for the first issue is a pen and ink drawing by the editor of a vertical drop that he himself would like to rappel into someday.

NO. 2

Issue No. 2 will feature vertical rescue techniques, the Swing open cam, and many others.

STATIS OF VERTICAL CAVING

by Bruce Smith

In preparation for the 1971 National Convention's Vertical/Rescue seesion, more than one hundred questionaires were sent to a representative number of grottos and clubs across the continent. The results of this questionaire seem of significance for self evaluation purposes and basic general interest.

Vertical techniques have reached a high level of sophistication in in recent years and it seems appropriate to pause and take a look where we, cavers, stand with regard to vertical techniques, vertical skills and vertical prowess.

Out of the 100 or so questionaires sent out, 46 replied representing some 2028 members of the N.S.S. Out of the 2028 people who answered only 1383 confessed to cave. Seven hundred and three or 46.4% of the professed cavers endeavored in the exploration of primarily horizonal caves, while 817 or 53.6% claimed to be proficient in both horizontal and vertical types of caves.

Vertical systems employed was the next major category. This must be interpreted as a time usage and not just usage; such as 63.1% of all rappels were brake bar rappels.

DESCENDING	
Brake Bar Rappel	63.1%
Rack	30.8%
Body Rappel	4.8%
Other	1.3%

ASCENDING	
Jumars	44.5%
Gibbs	17.7%
3 Knot	13.9%
Ladders	12.5%
Texas	8.7%
Heiblers	2.7%

Primarily, these charts show what cavers are using and an indication of the most popular modes of vertical travel.

The nest question was of no great importance, but proved to be very interesting. The total number of feet that each person climbed over one year, April '71 was the question. This number is more or less an initial index for forth coming years to determine how much experience cavers are getting and how many cavers are getting this experience. Since there is no comparison, it is just a fantastic figure with no meaning. Hopefully questionaires will, following, in the future giving meaning to this number and ohters like it. 2,246,600 feet or 425.5 miles were ascended by some 928 people which averages 2420.2 feet per person, or 62,018 feet per grotto.

Cavers cave just about anywhere that they can find a hole, but the caved areas represented by the questionaire can be described as a giant crescent starting in New York and sweeping down the Appalachian Mountains. The band increases in size across Texas, Mexico and the Southern states and back up in Oregon and Washington. According to the survey, members of 46 grottos made some 1900 cave trips over the past year. Most of these trips were reported as being the underground type.

These numerical statistics are indicators and only an index of what cavers are doing. Only by continuation of such a study can we keep in touch with our progress, our growth and our enthusiasm. It is hard to associate numerals with an intangible such as caving, but it is evident that these figures do show what's going on. It shows what methods people use to ascend and descend. It indicates the extent of caving skills. It tells what systems are being used and to what percent. It tells how far people are prusikking which is an indication of experience and hopefully versatility

If it were to be done over again and there were sufficient funds, I strongly suggest that the questionaire should be expanded, all terms defined and all questions explicit. Other than that I can't see too many improvements that need be made.

A questionaire like this can tell many more things in the future. It is an indication of the statis and where we sit/walk with regard to vertical work underground.

THE CARE AND FEEDING OF NYLON ROPE

by Kyle Isenhart

With the tremendous number of cavers doing vertical pitches these days, it is very important safety-wise to understand some things about the ropes to which we all entrust our lives.

What is Nylon?

Nylon is a generic term for a family of polyamides and is defined as: "Any long chain polymeric amide which has recurring amide groups as an integral part of the main polymer chain." Commercial nylon polymers very not only in molecular structure but also by molecular weight within each particular structure. Some of the common nulons are types 6/6,6/10 and 12. Within each of these types are high and low molecular weight grades. While the physical properties of these different nylon polymers vary widely, their chemical properties are very similar.

The name applied to nylon polymers in Europe is "Perlon". It is from the misunderstanding of meaning of this term that people often refer to the dynamic ropes manufactured in Europe as perlon ropes. While they are made from perlon polymer they are of kernmantle construction. Different rope manufacturers use identical nylon filaments and produce ropes with different elasticity and strength. The selection of a proper type rope depends upon its intended use but for most caving activities ropes such as Blue Water are best.

Care and Grooming of Nylon Rope

After purchasing a new rope and brfore its first field use it should be washed. This should be done for two reasons: to remove the oil and other luricants that inadvertently remain on the rope filaments from manufacture, and more importantly, to "set" the rope. This pre-use treatment of the rope is very important as it can increase the usable life of the rope many times.

The first time a rope is washed it will shring a considerable amount. This shrinkage is very important for several reasons: (1) It stabilizes the elasticity of the rope, (2) in laid ropes (e.g. Goldline) it tightens the strands, (3) on braid over braid ropes (e.g. Sampson West 707) it closes the openings in the inner braid and tightens the outer braid somewhat, and (4) on ropes of kermantle construction (e.g. Blue Water, dynamic climbing ropes) it tightens the sheath over the inner core and closes the openings in the braided sheath enough to prevent almost all penetration by mud and dirt to the inner supporting filaments.

While the problem of abrasive particles penetrating the sheath and cutting the inner strands is not completely solved by pre-treatment and frequent laundering, it can be slowed sufficiently to make kernmantle ropes usable for the life of the outer sheath. Allowing nylon ropes to become extremely dirty and using them in that condition not only destroys the rope but causes severe damage to expensive descending and ascending equipment. A dirty rope is NOT a status symbol. It generally denotes improper care. While all ropes eventually become dull colored and fuzzy from use there is no excuse for a 5/8" diameter mud rod with a 7/16" nylon core. Due to the fact that internal damage cannot be inspected in braided ropes it is extremely important to protect this type of rope from unnecessary exposure to dirt.

I have heard many types of rope cleaning procedures recommended and most had some merit. I have seen ropes pulled up rivers behind power boats, and I once met a your couple washing their most prized possession--a new 350' Blue Water in a creek with toothbrushes! It worked well but was a little slow. The most practical way to wash a nylon rope is in one of the big round front opening commercial washers at a laundromat. They have a large round sight glass in the door. Make sure it is glass instead of plastic as it is possible with a plastic window that during the spin cycle the rope could be rubbing against the window enough to generate sufficient heat to fuse a portion of the outer surface. It is best to put the rope in the washer in a loose bundle instead of a tight coil because it cleans more efficiently. Another important point is to make sure all the rope is inside the drum of the washer and not hanging out around the edges. Lengths up to 600' can be easily washed in this manner. Upon removal from the washer the rope will be tangled but patience and a little help from your friends will usually prove superior to the snarls. Washers with central rotating agitators should be avoided as the rope tends to become very tightly entangled about the agitator.

The proper water temperature and cleaning agent for nylon rope always brings up great controversey especially among those who know very little about cleaning agents and nylon chemical structure. Nylon polymers can withstand 180°F immersion indefinitely with no degradation of the polymer. Immersion in liquids above 300°F for more than a few minutes should be aboided. Water boils considerably below this temperature so what all this means that it is best to wash your rope HOT water. At most commercial laundries hot water is about 140°F, which is sufficient to do an excellent cleaning job.

The next question is what kind of cleaning agent to use? Our research department (Marbon Chemical Division of Borg-Warner) decided not long ago that the company should enter the soap business so we did extensive investigations on commercially available cleaning agents. I am not pushing any products, just sharing some results of our research work.

Some purists recomment natural soaps like Ivory. Their fault is that the natural soaps lack the necessary additives to keep the removed dirt suspended in the water so it settles back on the surface of articles being washed. The result is that while they don't hurt anything they don't clean very well either. All detergents when dissolved in water are alkaline, and clean by the action of either phosphates or carbonates. Nylon is not affected by such alkaline conditions. All soaps and detergents available at the grocery store for laundry use can be safely used on nylon. The best liquid cleaning agents for nylon are the detergents such as Wisk, and Liquid All--the best powder detergent seems to be Tide. The use of special pre-soaks such as Axion and Biz before washing is of little value. If you have a white nylon rope and want to bleach it that is all right also. Do NOT use chlorine bleach, but try one of the others abailable at a grocery store for nylon. There has been some question raised about Borax. Borax will NOT harm nylon. You can even use a little Bo-Peep ammonia it if turns you on.

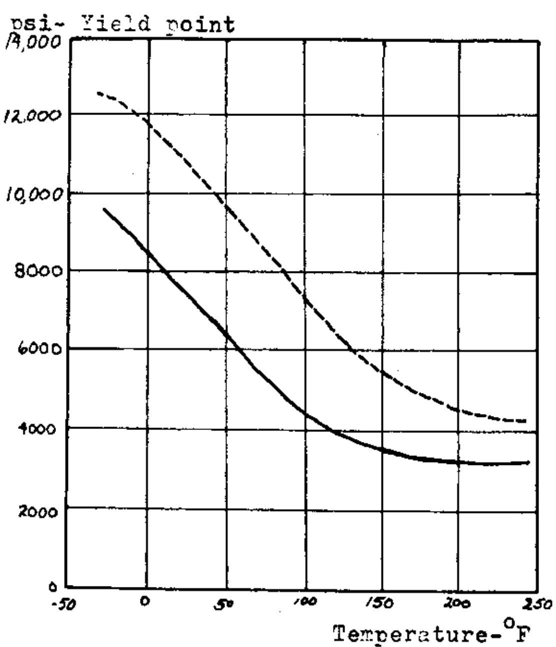
Since some ropes tend to become very stiff after extended use, everyone sooner or later ponders whether to use fabric softener on their rope. Softeners work by the action of Quaternary Ammonium Salts. These salts adhere to the furface coating. This coating is very slick and allows the fibers to slip past each other with very little friction. This lubricating effect increases the flexibility of the material which people interpret as being softer when in reality it is only more flexible. These ammonium salts have no harmful effect on nylon and the use of fabric softeners on rope is quite advantageous.

The sofener's coating on the outer surface of the rope causes it to feel waxy but it wears off very quickly. The first person to rappel on a rope treated with fabric softener will notice it is quite slick but by the third rappel it will not be voticeable. Besides making the rope more flexible softeners have other advantages. That portion which penetrates to the core of kernmantle ropes lubricates the minute filaments and helps keep them from abrading on each other while the rope is flexing. The softener also forms a barrier between the ropes nylon fibers and dirt particles. All the good quality rofteners (e.g. Downy) are effective on nylon. If you are afraid you will miss the final rinse cycle use a softener such as Johnson's Rain Barrel which can be added initially with the soap. After washing, the rope should be dried before storage. While drying the rope in a dryer would be acceptable (if the drum doesn't get too hot,) it is much better to hang the rope in the air to drip dry.

What Attacks Nylon Rope?

Nylon is an extremely inert polymer. It is resistant to most solvents, alkalies and even weak acids. Nylon is attacked by strong mineral acids such as sulfuric (battery acid) and other strong oxidizing agents. It is also degraded by sunlight over an extended period. The type nylon used in rope will slowly degrade at temperatures above 180°F and will degrade very fast at temperatures above 240°F is exposed to air. Do NOT store a nylon rope on the back window shelf of your car. While nylon melts only at high temperature, its tensile strength decreases rapidly as its temperautre increases (see accompanying graph). Nylon is dissolved by liquid phenol and formic acid, neither of which I have ever seen in a cave. Formic acid is in most insect stings and ant bites. Phenol (carbolic acid) is present in many wood preservatives. The nylon used for rope is not attacked by gasoline, anti-freeze, beer, urine, bat guano, whiskey, brake fluid or oil. It is inert to all foods that are edible by humans. It is difficult to find a substance that will attack a nylon rope around your home or while out caving. Specific chemical resistance data on many substances is available from the author if you have any further questions.

Effect of Moisture content and Temperature on the yield stress of nylon.



------Average air exposure(2.5% moisture)
———Saturated (8.5% moisture)

Amost appealing feature of nylon ropes to cavers is the fact that they do not rot or deteriorate from exposure to water; however this is a very misunderstood phenomena! There is an interaction between nylon and water and your nylon ropes physical properties are highly dependent upon the amount of water entrapped within the polymer structure. This may seem confusing, but the nylon filaments have small spaces between the molecular chains that form them. The amide structure has an affinity for water and small numbers of water molecules penetrate the nylon filaments to fill these open spaces. While many physical properties such as modulus of elasticity, abrasion resistance, melt softening temperature, and flexural fatigue are also affected by the percent of absorbed water, we will dwell mainly on its effect on tensile strength. Nylon has such a high affinity for water that after manufacture it is never dry. The types of nylon used to manufacture rope come to equilibrum in a 50% relative humidity atmosphere when they contain about 2.5% absorbed moisture. This water is absorbed directly from the air and there is no way to prevent it. Most manufacturers' specifications for nylon ropes are based on ropes in which the nylon polmer has 2.5% absorbed moisture. This is about what your rope has if you store it around the house. The problem is that as the moisture content of nylon polymers increase, its tensile strength decrease rapidly. I had not given this much thought until I heard some people advocating soaking ropes in water before doing long rappels to help prevent the rappel devices from overheating. I have discussed this with technical representatives from several major nylon manufacturing firms and they all felt it was a bad idea. The water saturation point of nylon filaments the size used for rope manfacture is reached in a matter of minutes and the tensile strength of the polymer is drastically reduced (see the above chart). Because of this fact the use of standing ropes in wet drops should be discouraged as well as the practice of saturating ropes before use. It could be that cavers have been very lucky thus far that a water soaked rope hasn't broken. I hope our rope suppliers will test some saturated ropes in the near future and shed some more light on this subject.

Heat too is a potential enemy of nylon ropes. People are very concerned about overheating rappel devices on long pitches. The problem is that nylon like most polymers does not have a sharply defined range of temperature at which it is usable. Nylon filaments used for rope manufacture can withstand 180°F air exposure indefinitely without degradation. At 240°F they degrade in a matter of minutes. The real question though is just how hot can a rappel device become while incontact with the rope. This depends upon the pressure and time at the point of contact. A 180 pound caver applies almost 70 psi load on the rope in the areas contacted by the brake bars during rappel. At this loading nylon can withstand just over 300°F before softening to break under the load The therman conductivity of nylon rope is so low that if the sheath were in contact with a 300°F brake bar long enough and enough pressure were applied to melt the surface, the rope 1/8" away would still be near ambient temperature. While this in no way solves the heat problem it does show that if the rappel device overheats and fuses a section of the sheath while moving on Blue Water it still retains nearly 92% of its initial strength. This is considerably more than a water-soaked rope with the same internal temperature. Further field testing will be required before specific recommendations concerning safe rappel device temperatures can be made.

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Guide to Plastics by the Editors of Modern Plastics Encyclopedia Engineering Properties of Zytel Nylon from DuPont De Nemours & Co., Inc.

Typic Properties of Nylon Resins from Celanese and DuPont

Other literature and reports from the files of Marbon Chemical Division of Borg-Warner Corporation

Reprint from Georgia Underground

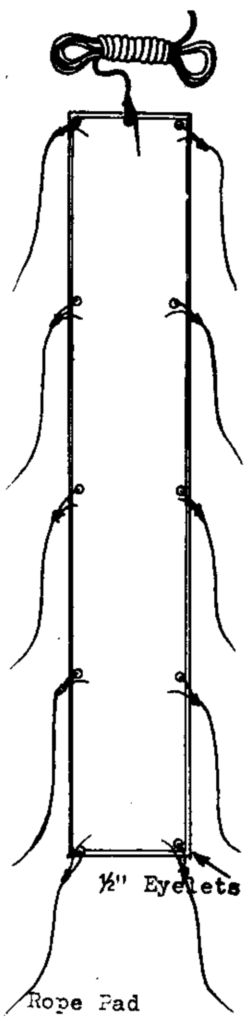
ROPE PADS

by Bruce W. Smith

Much concern has been brought into the vertical cave scene with regard to rope pads. Incident after incident has pointed up that rope pads were needed but there use neglected. Ropes have been abraded, severely damaged and even cut because proper padding was disregarded. I propose here to present an established workable construction of a rope pad, the situations where they should be used and especially how to to use them.

Construction

Bill Cuddington proposes this following construction. Pads are usually constructed with some heaby fabric or non-nylon carpet. A very heavy duck canvas, which is available at a good fabric center or theatre supply house is a good versatile medium to use. The pad's width should be about two feet but the length will very from 6 to 15 feet. Teh canvas should be hemmed all the way around to aboid fraying. Now proceed to your local tent and awning shop and have him place ½" eyelets as shown in Figure #1. Attach some strong nylon cord to the various holes with bowlines or some similar knot. The side hole cord lengths need only be about 2 feet long, while the center top should be 15 to 25 feet long and made of 3/16" or ¼" nylon cord for it may have to withstand a load bearing force. A stiffener of sorts would be helpful in the top hem. See Figure #1 for details. It should be mentioned; fireproof carpet is a must if one chooses the carpet route.



Rope Pad Construction
FIGURE # 1

Where Needed

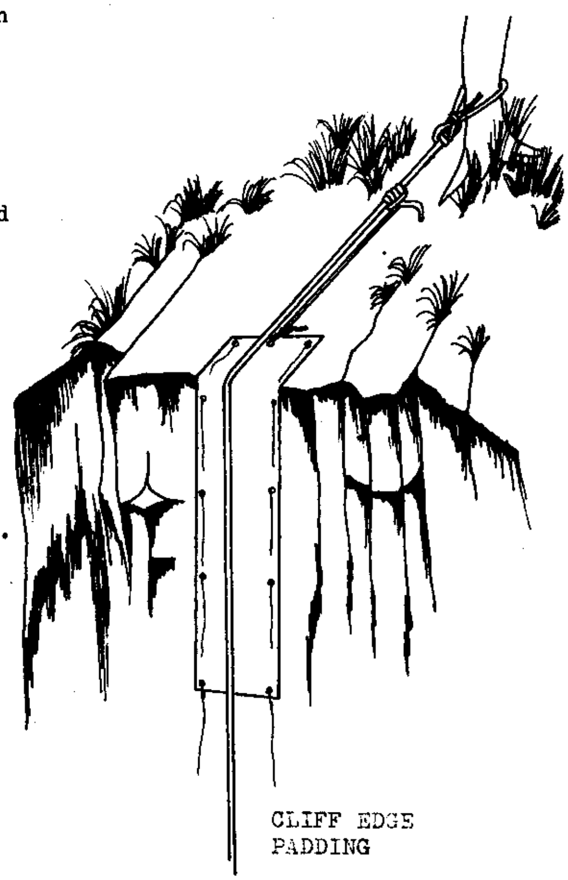
Anytime a suspended rope comes in contact with a rock face, beware of the need for a rope pad. If a stretchy rope is being used such as Goldline or Perlon, be especially cautious, for the bouncing effect produced by a climber can, even on an appearing smooth rock face, abrade the rope severely. If the rope should ever come in contact with sharp rocks such as chert or shale there is no question that a pad is needed. If the rope ever should break over a sharp edge, pass around a jagged boulder, or need be stretched around a corner in a passage, proper padding is again necessary. If the rope ever should come in contact with cave coral or rough popcorn a pad is definitely necessary. These are a few of the primary placed where padding is necessary. The final decision as to whether or not to use a rope pad becomes a judgement on the riggers part, that hould be based on experience.

How To Use A Rope Pad

Here to follow will be the location and suggestions for securing a rope pad. The most common situation would be where the breakover is rough and needs to be padded. If your main line rig point is close, tie the long top center pad cord to your rig point and drape the rope over the pad at the edge. If the rig point is not close enough then fasten the long top center pad cord to the rope itself with a prusik knot as shown in figure # 2.

If the point to be padded is 20 or 30 feet below the breakover point then as each climber begins his rappel he should be instructed to slide the prusik knot down the rope with him thus positioning the pad at the proper place. This method is only good when the distance that the prusik knot be moved is small, for it would be too much trouble to raise and lower a knot a great distance each time a climber rappelled or prusiked. Obviously this method would not work with tandom climbers unless your pad was long and the climbers ascended close together. If the point to be Padded is a great distance from the breakover point then a completely separate rope should be rigged with the pad dangling from the end. If the pad is being used on a cliff or windy place where there is a chance that the pad may be blown from its strategic position position, use the side cords and tie the pad around the rope. See fig.#3.

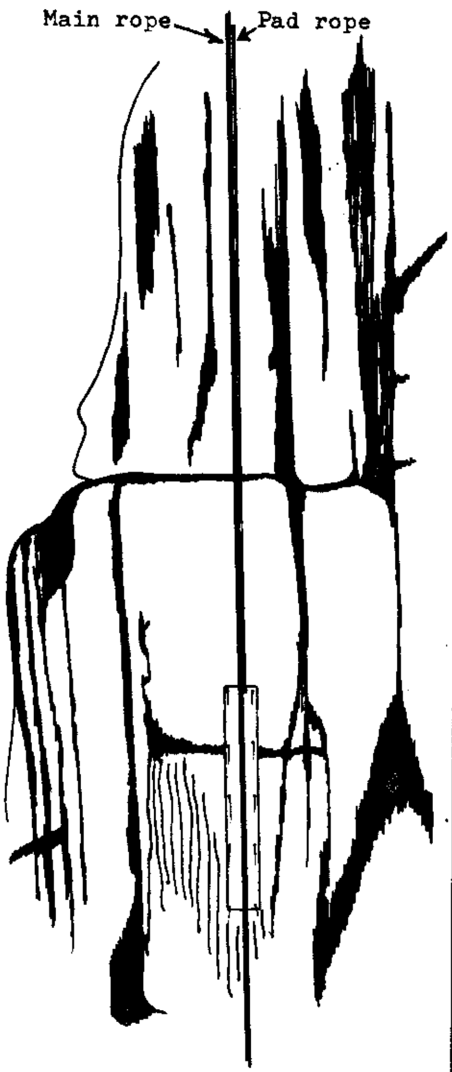
If the rope is tied to a sharp or jagged rock, the corners should be padded either with a rope pad, rope bag, heavy leather gloves or some heavy article of clothing. Rope padding should be a conscious thing, and the awarement of the need is half the battle against damaged rope not to mention bodies. One particular incident relates experienced cavers, rope pads, and Dantes Descent. The rough walls had been adequately padded. During the ascents and descents one part of the rope slipped off the pad near the top and the rock sawed through 70% of the



CLIFF EDGE PADDING

FIGURE # 2

new Blue Water II rendering it useless. Care and caution should always be the rule and rope pads are good insurance measures.



ROPE PAD ON A CLIFF FACE

FIGURE # 3

JUMAR-GIBBS DILEMMA

By Bruce W. Smith

As a caver progresses to the modes of vertical ways he needs to make the big decision. Out of all the ascending systems available, there are several that are right for any one person. But Joe Caver has decided he wants to go mechanical, so after weighing all the isues, he has come down to a choice between two types of equipment--Jumars or Gibbs. Does it sound familiar? He has enough money to buy either, but can't afford both. The best answer is to buy them both, but financial consideration must be taken into account. Besides, he is looking for a system that works universally well under all conditions.

There are pros and cons to both devices and it is the intent here to go into them both. First, the Giggs; as proven in the 1971-2-3-4-5 Convention Prusik Races, Gibbs' cams are the fastest of all the devices. They are the cheaper of the two devices under discussion costing around $15.00(now $22.00) a pair. Gibbs work on all sizes of rope up to ½" and can ascend a rope stretched at any angle. They have a good positive ascending action with little fall-back if rigged correctly. Gibbs test up to 2,250 pounds, but are only advertised as 1,000 pounds tested. They are the highest testing ascending device. Gibbs don't rust, crust orcorrode and can be used under any environmental condition. They work on iced rope, in mud, under a direct waterfall, in dust and fog. Mud causes minor problems at low rope altitudes, but with a bottom belay or by pulling the trailing line under the left instep with the left hand (assuming foot cam is on the right foot), this problem can be overcome. They can be arranged to work with the Texas prusik system very effectively or any other system for that matter, but can be best used either as Charles Gibbs advocates or in the "Floating Cam" arrangement. The Floating Cam system seems to be easier to put on and has been proven as the fastest ascending arrangement on the rope (Convention '71-2-3). The shoulder cam is a definite positive score for the Gibbs. With the cam on the shoulder, the rope is held as close to the body and the body's center of gravity as possible.

However, the Gibbs do have two major drawbacks--They are not convenient and they do not descend efficiently. Gibbs cannot be removed from the rope and replaced with the ease that one may desire. Although this is only one point, ease of equipment manipulation underground is a very important consideration. Because of this, Gibbs are impractical for a safety attached to one's seat harness while Jumars can conveniently be used for a safety during a rappel.

A system should be capable of being used for all types of manipulations and among these is descending. Gibbs do not descend efficiently. It is possible to descend somewhat slower than descent with the Texas system, but this is highly inadequate. It takes a lot of practice and effort for a climber to become proficient with cams on a descent.

Jumars also have many fine qualities and were the second fastest ascending device used at the Convention '71-2-3- Races. They have tremendous positive cam action that can be taken full advantage of if non-stretch cords are used with them. They are made of an aluminum alloy that won't rust, crust or corrode either, except the steel piano wire springs on the safety and cam piece occasionally rust slightly. Jumars are tested around 700 pounds and are expensive--about $32.00 a set from most dealers. If the teeth tips have been worn a little bit, they may also rust.

The Jumar's environmental working range is it's drawback--they refuse to work at all on iced rope. The cam freezes to its mounting and will not pivot. The teeth become encrusted with ice and will not grab. In mud they have their difficulties too. They will work in oozy mud, but in clay or crusty mud the teeth clog and slip. It becomes essential to check and clean the teeth regularly. A toothbrush works best, but a tip cleaner is adequate. Jumars do work well in waterfalls, dust, and fog. Be cautious when the rope is not hanging perpendicular from the cam because the bite angle of the rope may put undue stress on the safety catch and cause it to falter.

Jumar cam can be thumbed and no belay from below is needed. Jumars descend almost as efficiently as they ascend. Jumars can be used on all sizes of rope up to $\frac{1}{2}$". File 1/8" off the safety if $\frac{1}{2}$" use is desired.

For the best ascending results with Jumars, three are needed. Incorporate the Mitchell System with a seat Jumar that will just reach over the ascender box. With these three Jumars, any climbing situation can be overcome. The Mitchell system is good for free drops, and fairly vertical faces. Change over to Texas Method if the face is irregular. Manipulate the main rope out of the box to get over an overhang. If the face is 60° to 80°, switch over to the Cuddington Third Phase. There are also other combinations which work well and any climber can work these out on his own. This is the beauty of Jumars--they are versatile. They can be adapted to any situation. Jumars can be instantly modified for belay safeties of all types. They can be clipped on and off the rope at will with no difficulty which is probably the main reason Jumars are internationally famous among climbers.

In direct comparison we find only a few points of immediate interest. Gibbs are free-working under all conditions, while Jumars clog under mud and ice. Gibbs can be practically used on the shoulder while Jumars require a chest box or chest harness to keep the climber vertical. This is of no major consequence except the chest box doesn't allow the body to hang at its maximum vertical angle. The legs must work much harder if the climber is not vertical. All the energy that is directed at any angle other than that of the rope must be transferred in the direction of the rope. Any vector student can easily understand that a lot of energy is lost in a situation such as that just described. Jumars clip on and off the rope easily while cams require some time and care to incorporate onto a rope. Gibbs are fixed to specific harnesses while Jumars with their long leg straps can be used for many tasks. Gibbs are faster, but Jumars are not that much slower. Jumars ascend and descend efficiently, while Gibbs only ascend efficiently. They both require a similar amount of energy furing similar ascents.

In the author's opinion, Gibbs are the finest system to use if all drops to be climbed are long and gree; but for tricky maneuvers, emergencies, and versitility the Jumar seems to be best. If the swing-open cam were developed commercially then I may change my conclusion.

There is a relatively new system under experimentation called the Pygmy System, that incorporates most of the finest points of both ascending systems. The three-Jumar Mitchell System is the same except the ascending box is omitted and both foot Jumar straps are shortened to the individual. The rope passes through a shoulder cam for prestated reasons. Retain the seat Jumar

for a rappel safety and other changeover requirements. In essence this system requires three Jumars a Gibbs's seat harness and cam shoulder harness complete with Gibbs. Jumar cords can be shortened by whipping the cords around a carabiner several times to achieve the correct lengths. If a climber totes along an ascending box he can use any method he desiress, Mitchess, Texas, Cuddington third phase, or Pygmy. The Pygmy System was designed especially for long drops where the upper arm tends to get tired. It worked quite adequately up Fantastic Pit.
Bulk reprinted from the Georgia Underground

RIGGING THE FLOATING CAM SYSTEM

"Fastest Ascending System Yet Known"
by Bruce W. Smith

The Floating System was proven to be the fastest ascending method available at Convention '71-1-2- Races and the purpose here is to present a practical, economical way to rig this system.

To begin with, we'll get the lower right foot Gibbs out of the way. There is no super way to attach this cam yet. Some people advocate a stainless steel eight pound stirrup, while others recommend steamer trunk buckles on one inch tubular webbing, but until someone can come up with a truly good idea, the author suggests the following. It works. Take a long piece of one inch tubular webbing and before you're done, the webbing will have been wrapped around your instep twice and ankle once. Refer to Figure #1.

The left foot gets a little more complicated and is where we begin to gloat. One inch tubular webbing is still the best material here. Tie a slip knot in one end of the webbing and stitch the end to the standing area of the webbing. This loop is inserted onto the boot and will eventually be stood in. Leave enough slip knot sliding space to allow for loosing of the foot loop from your boot. See Figure #2. Attach the knee Gibbs to the other end of the webbing. The eye of the cam should fall 3 to 4 inches above the center of the knee cap. Stitch the end to the standing part of the webbing as shown in Figure #3. Don't forget a chicken loop.

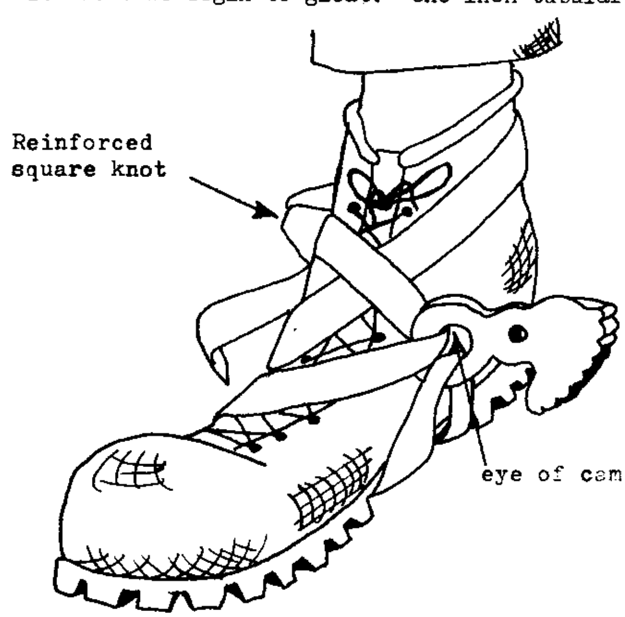


FIGURE # 1
Foot Cam

Fabricate two small pieces that will be used as connectors that will attach to surgical tubing. The original design was developed by David Sponaugle of Franklin, West Virginia. You will probably have to visit you local welder to attach the nails to the steel plates. Now push two pieces of surgical tubing onto the nails of one connector. Wrap each tightly with stiff baling wire. Clip the connector on the float cam, put the loop in the left foot and lift that foot as high as possible, simulating a giant Gibbs step, and without stretching the piece of tubing, pull the whole mess in a straight line to your collar bone on our left shoulder and mark the surgical

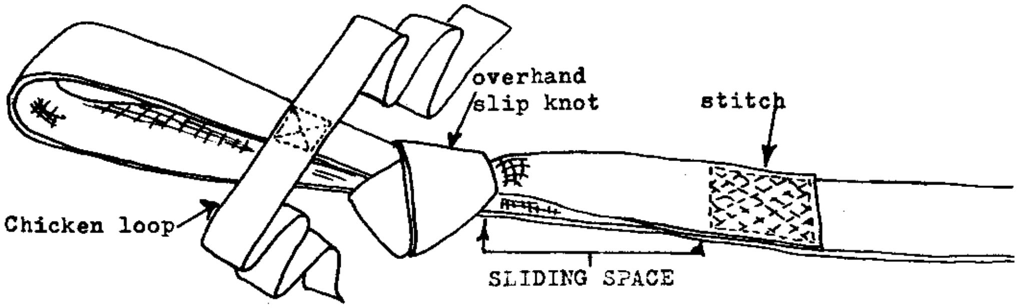


FIGURE # 2

tubing at that point. Cut it there. Connect the other two ends of the surgical tubing to the two nails on the other connector and wrap tightly with wire. See Figure #5

Put all that aside for a shile and concentrate on the upper rigging. Construct a Gibbs harness including at least four stitched joints and can have six. Be sure to taper the strapping at the point where the locking carabiner will fasten as shown in Figure #6. Use a 13/4" or 2" strap for the harness. The harness is made from one piece of strap and is used primarily because of its non-shifting properties. This is important when it becomes time to attach the back strap from the shoulder cam. See firgure #7.

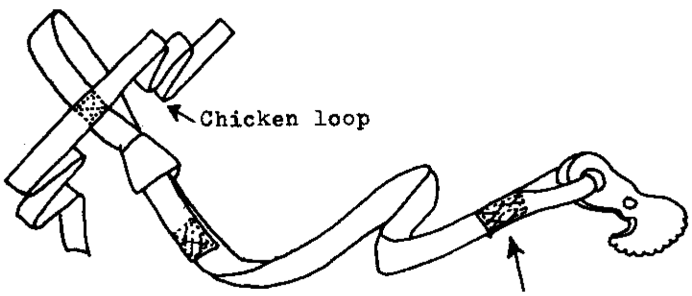


FIGURE #3
FLOAT CAM FOOT STRAP

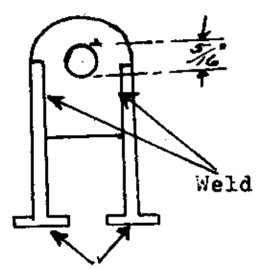


Figure #4

Begin the construction of the shoulder cam. Taper one end of a piece of strap as shown in Figure #6 and insert it into the eye of the shoulder cam. Sew the end back around to form a loop in the end of the strap capturing the eye of the cam within. Position the cam on the sleshy part of your shoulder. Stretch you seat harness (which you should have on) from the carabiner as if you were sitting in it. Stand erect. Now, mark the point on the shoulder-seat strap where it meets the carabiner. This mark now becomes the inside end of the next loop to be sewn. Figure #8 should look similar to your handiwork.

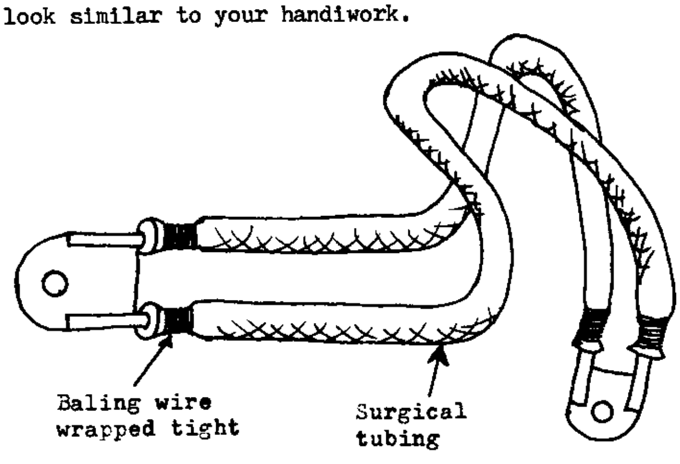


FIGURE # 5

Now, stitcy another taper and sew it on the shoulder cam exactly as you did the front strap only this one will drape across your back. Stitch a cinch buckle to the end of the piece of strap at a point easily manipulatable, but as high on your back as you can reach with both hands.

The last thing to stitch goes on the harness. Sew one straight piece just behind the left crossover on the seat harness angling it up towards the right shoulder. Cut it about 1½ the distance from the crossover to the buckle on the upper back strap. See Figure #9.

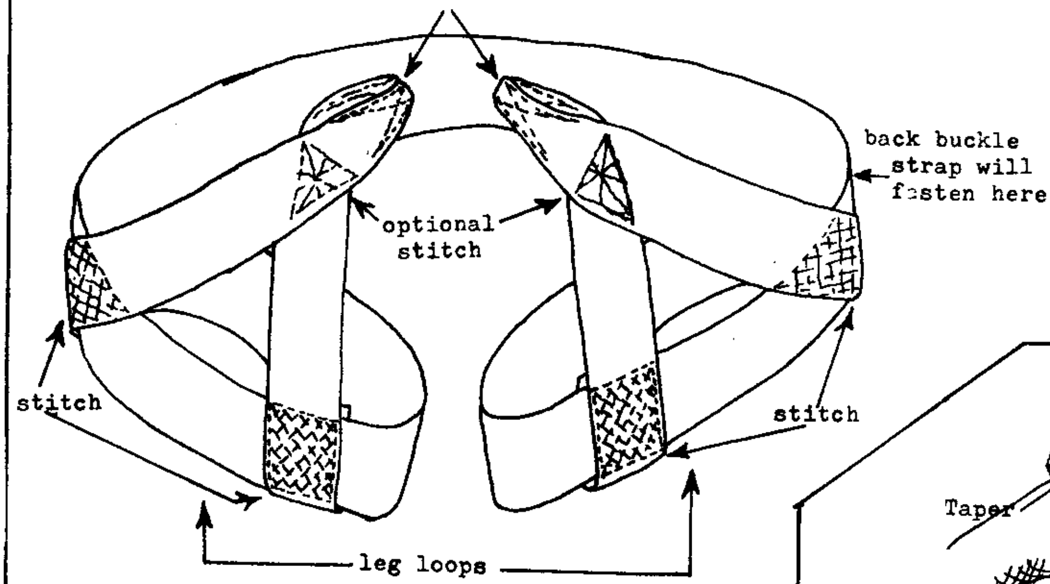


FIGURE # 7
GIBB'S HARNESS

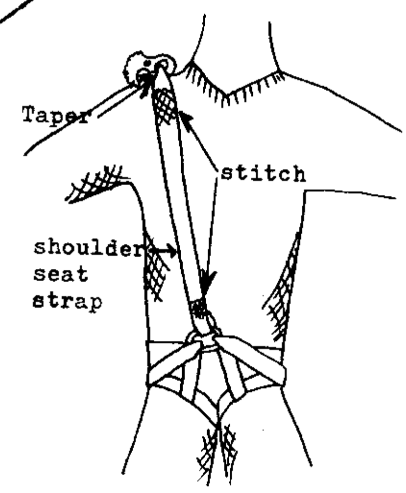


FIGURE # 8
FRONT VIEW

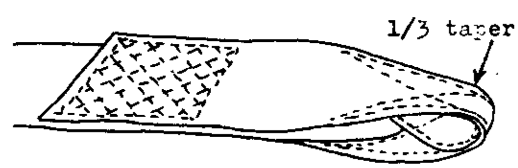
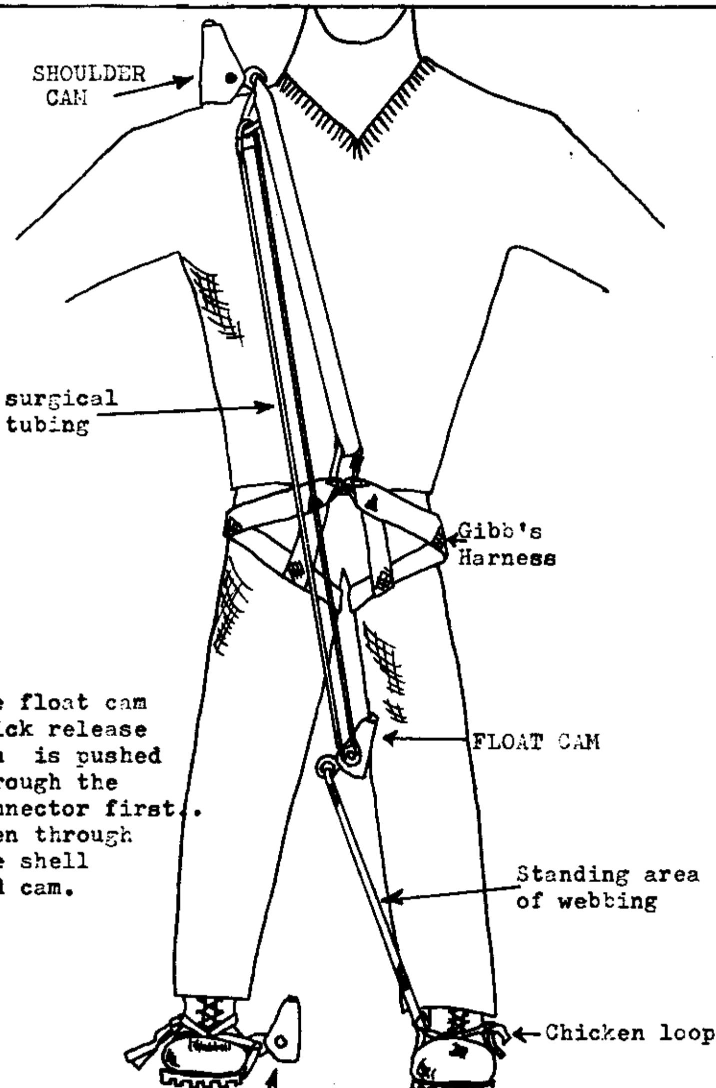


FIGURE # 6
TAPER



The float cam quick release pin is pushed through the connector first,. then through the shell and cam.

FIGURE #10
FLOATING CAM SYSTEM

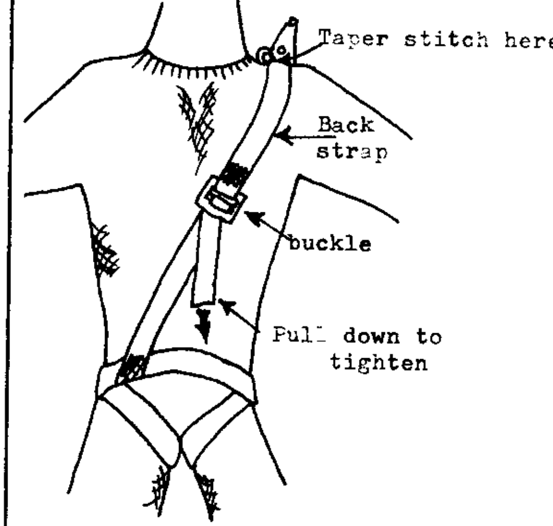


FIGURE # 9
BACK VIEW

Buckle the strap up and pull down on the tail piece to tighten it. Put your right foot cam on. Put float cam foot loop on and clip a small steel carabiner (pear shaped) in the top loop of the shoulder-seat strap and you should be ready for competition racing, besides any caving you may want to do on the side. See figure # 10.

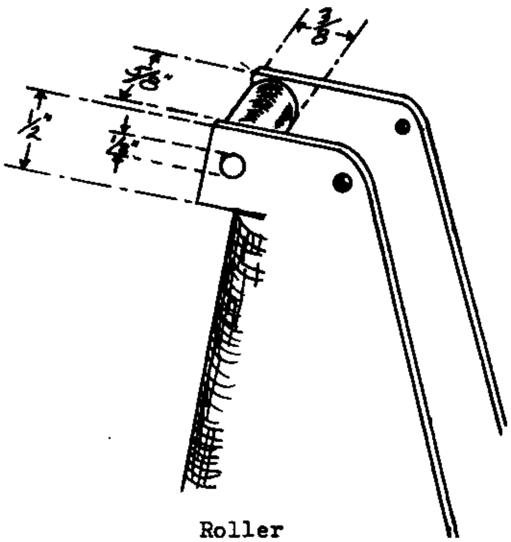
*Author Explanation: Throughout this article I use the term Gibbs and Cam interchangeably foe a Gibbs is one variety of a cam even though there are no other commercially sold cams.

Portions reprinted from the Georgia Underground.

ROLLER CAM

By Kyle Isenhart

The roller cam was developed in the spring of 1972, by Kyle Isenhart and Delbert Province and presented at the 1973 NSS Convention. This cam is designed to replace the shoulder cam used with Gibb's cam system or the Floating Cam system with design and intent of reducing the vast amount of friction developed while using standard Gibbs. The alteration is simple: 1. Make two cuts in the top of the cam. The vertical cut should be ½" mark and through all the curved portions of the aluminum. 2. Bend out and flatten these two tabs. 3. Drill 1/8" holes dead center of the two tabs. 4. Cut off 5/8" of steel or hardened brass rod and drill a hole 1/8". Ream out the hole so that a 1/8" steel pin will glide freely inside. 5. Press fit the pin and roller into the two tabs. If one desires he may contour the roller to fit a standard rope.



Roller Cam

This roller cam can reduce the shoulder cam friction as much as 70%. This information was submitted by Kyle Isenhart but written by the editor.

FLOATING CAM SYSTEM ANALYSIS

by Bruce W. Smith

The Floating Cam System incorporates the finest of all the cam riggings to date. It was proven to faster than any other system at the 1971-2-3 Convention Races.

The system is basically a combination of four men's work: Charles Gibbs of Ohio, Kirk MacGregor of Canada, Kyle Isenhart of West Virginia and the author. Using Charles Gibb's famed cams along with his designed seat harness and recent shoulder cam improvement, we have the basis for the system.

Next we remove the knee cam from the knee and use Kirk MacGregor's elastic bands that connect the knee cam to the shoulder--the force that pulls the knee cam up the rope. Replace the rubber bands with a more conventional surgical tubing and connect it to the knee cam with the aid of a double nail connector, as proposed by the author. Our system in now complete.

The adv antages of this system are numerous. With the cam floating, the efficiency of the of the system and simplicity of rigging the system afford this system with the label of "The fastest ascending system." First of all, the floating cam can be put anywhere (within reason) on the leg and it will work. It is no longer critical as before with the rigging that Charles Gibbs advocates. Secondly, with the cam floating, the rope follows a straight path from the top cam to the bottom. The rope is never jerked from its natural hanging position by the knee stroke; thus saving energy, saving the rope, reducing fricition resistance and gaining precious inches with each knee stroke. There is no sloppy play in the system from webbing stretching or from elastic stretching off the knee. The action is simple: The shock cord pulls the knee cam up to any desired height. The foot cam need not clash against the knee cam. The knee straps need not bind or be uncomfortable any longer.

The shoulder cam allows the body to hang at the highest point possible, thus enabling the body to hang close to the desired position of completely vertical. The closer the climber is to absolute vertical during walking ascents, the less work he must do. It is basically a problem of force vectors and exerting energy in one direction to achieve motion in another. Walking up rope should be easy as walking up stairs. This hanging position problem is magnified with the use of the ascender box and more so with a chest carabiner and it becomes ridiculous if a seat harness carabiner were to be used.

Looking back we find the four major advantages that this system has to offer. 1. It is the fastest ascending system yet known, 2. This particular cam rigging is the fastest to put on and make ready, 3. It is more comfortable and easier to use than any previous cam system and 4. It is practical for caving.

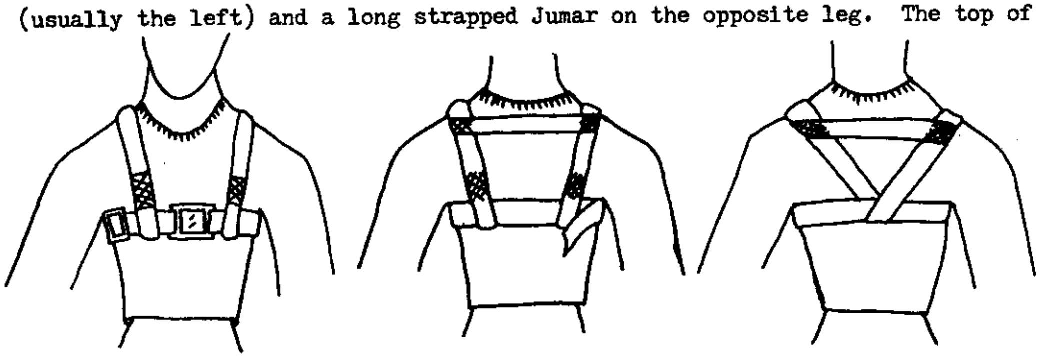
EFFICIENCY WITH VERSITILITY: JUMARS

By Bruce W. Smith

The widely acclaimed climbing device known as the Jumar if used to the best advantage can be the most efficient and versitile piece of climbing equipment a caver may own.

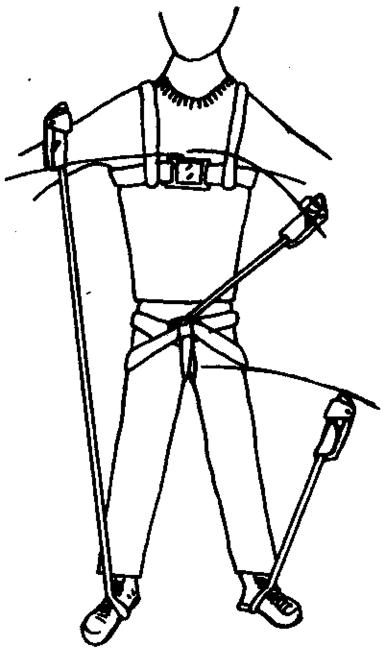
The Jumar system conglomerate has primarily been made possible by the contributions of Dick Mitchell, Keith Wilson and Bill Cuddington. With the invent of the Mitchell System and the incorporation of Wilson's "Wheels" or the chest box we have the fastest way of vertical ascent on a rope with Jumars.

The Mitchell System uses two Jumars, primarily a short Jumar on the climbers weaker leg (usually the left) and a long strapped Jumar on the opposite leg. The top of the short strapped Jumar should be placed for a comfortable reach about crotch level. The second long strapped Jumar is positioned high on the chest just above the chest harness. The chest box helps the friction factors and should be fastened to



FRONT VIEW BOX — BACK VIEW H-STRAP — BACK VIEW V-STRAP

FIGURE #1



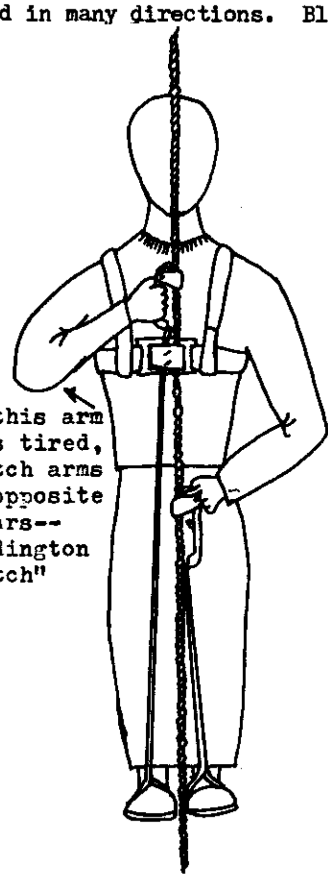
Mitchell-with-a-third-Jumar.
SLING LENGTHS

FIGURE # 2

the chest harness. See figure # 1 for chest harness suggestions.

The harness consists of three pieces: 1. The chest strap should be a heavy two inch buckled strap about four feet long. 2. The H-strap must be a tight fit and should position the chest strap as high on the chest as possible. It is convenient to sew the loops on the ends of the H-strap large enough to pass the two inch buckle through them. 3. The chest box has taken many forms in the last 3 years. Starting with Wilson's dog clips and "wheels" the box has evolved in many directions. Blue Water Ltd., sells the only commercial box so all reference shall be made accordingly. A third Jumar to the Mitchell System is the key to its versitility and efficiency. Attach this third Jumar to a seat harness and make the Jumar strap just long enough to reach over the top of the chest box. See figure # 2 for the complete Mitchell-with-a-third-Jumar System.

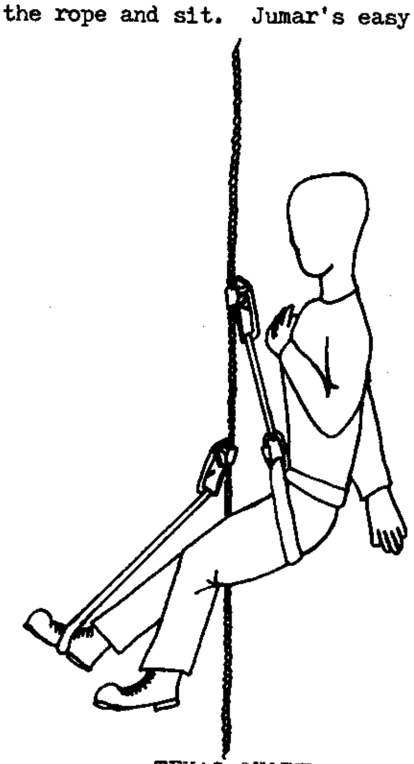
To climb using only the Mitchell System, clip the seat Jumar to one's side; if the climber needs a rest or needs to take a picture he need only clip this third Jumar to the rope and sit. Jumar's easy clip-on, clip-off advantage makes them outstanding over almost all other ascenders. I shall refer to the Mitchell System as the "Primary System." See figure # 3 on next page.



MITCHELL SYSTEM
PRIMARY SYSTEM

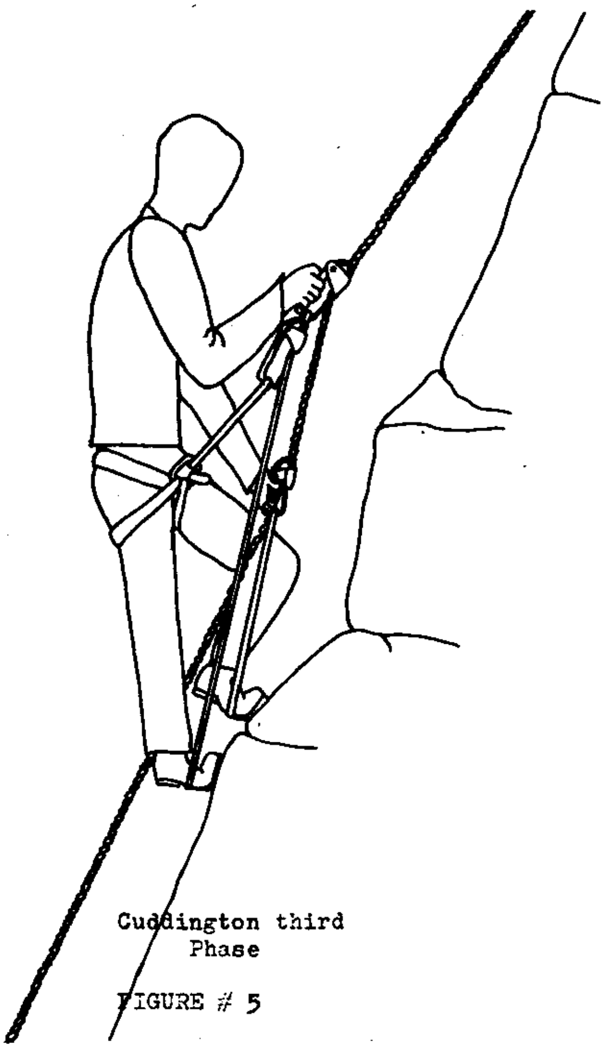
FIGURE # 3

The secondary system consists of the short foot Jumar and the short seat Jumar. This system is more commonly known as the Texas Prusik System. The Secondary system is extremely useful when the drop is small or against an irregular wall or any situation where the climber must negotate through a strange shaped pit or tricky overhang. See figure # 4. The Cuddington third phase requires the use of all three Jumars and is used for ascending up a face that ranges between 60° and 80° such as those found on Stone Mountain, Georgia or the Jumping off place in Schoolhouse Cave, W. Va. to mention only two. The box is not used. Both long Jumars hook to the rope as usual. The seat Jumar hooks to the long Jumar strap just below the Jumar. As a climber ascends the face he should adjust the seat Jumar up or down the long strap to find the optimum working position for that particular slope. See figure # 5. Notice that the seat Jumar replaces the function of the box.



TEXAS SYSTEM
SECONDARY PHASE

FIGURE # 4



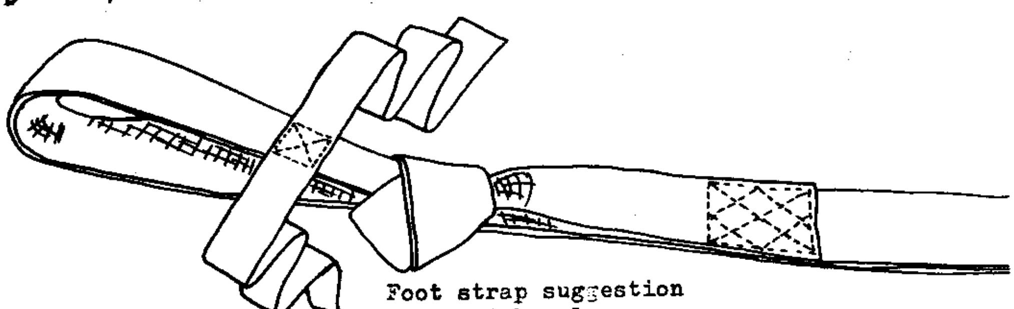
Cuddington third Phase

FIGURE # 5

The strap lengths are critical. Every strap must be fitted for one particular size person including the H-strap. The straps should be measured with tension on the straps and wash the straps first before measuring. Straps should be kept clean so that embedded dirt won't cut the nylon fibers. The way the straps are fastened to the feet are important. There are several acceptable methods. Figure # 6 suggests one such method because it can be loosened and tightened easily and can be easily fitted to any size boot. It is strongly recommended that the over hand slip knot be untied after every cave so that the knot doesn't become too tight to function properly. The foot loop can be made perfectly safe with the addition of a strong sewn on chicken loop as also shown in figure # 6.

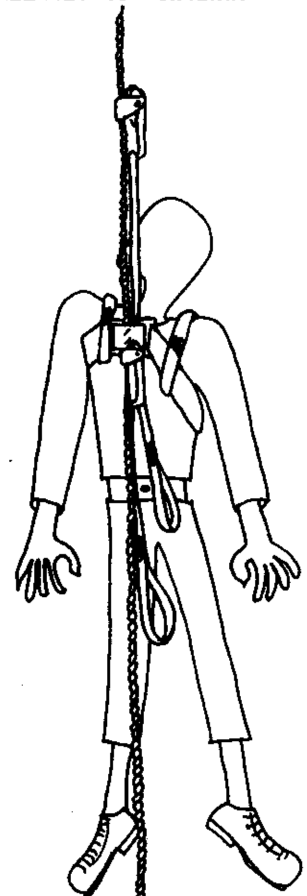
<u>System's Safety</u>

Lets consider all the possible things that could go wrong. If either Jumar strap were to fail in anyway the other strap would catch the climber and there would be a third Jumar available to continue the climb. If both straps were break or come off the climbers feet which is highly unlikely, he would be caught by his own box as depicted in figure # 7.



Foot strap suggestion with chicken loop

FIGURE # 6



Foot loops slip, Box rescue

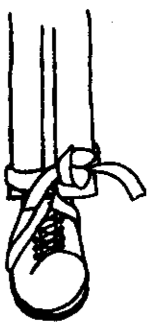
FIGURE # 7

If the box or any part of the chest device would fail the climber would flip upside down, (if the chicken loops are fastened securely), he would not fall to his death...Mitchell-with-a-third-Jumar, A good, safe, efficient and versitile way of vertical travel.

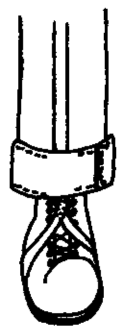
CHICKEN LOOPS: A MUST

by Bruce W. Smith

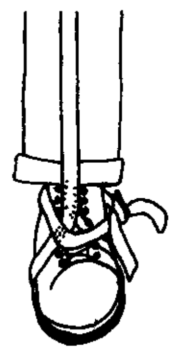
So you've managed to stay alive so far without using chicken loops. Consider yourself lucky for if you contimue in your non'chicken loop environment surely your days are numbered. Analyze for yourself all the methods of prusikking. Everyone requires the use of some cord, strap or sling fastened to at least one foot. If the strap should brcome loose and fall off, chances are you could find yourself in serious trouble. For example: While Texas prusiking your seat carabinr fails and disconnects from your top ascender. Your only recourse is your foot ascender. A chicken loop here will mean the difference between your life or your death. Let's consider several possible types or styles of chicken loops.



Tied piece of webbing around ankles



2" strap sewn to cuff



1" strap sewn to foot sling and tied

Of course, there are others than those mentioned here. One could easily incorporate cinch buckles or other fasteners. There are a few don'ts that should be mentioned. Do not use shock cord, rubber straps, surgical tubing, or shoe laces. The chicken loop must be able to support your weight.

THE SUPER RACK

by Kyle Isenhart

Ever hear of a super rack? That is the name in Parkersburg, W. Va. for the greatest new invention for cavers in years!

With the advent of extremely deep vertical pitches spelunkers were faced with the necessity of inventing a new rappel device. Various ideas were tried, but none gained the popularity of the rappel rack. Many different sizes were made, from six inches long with three brake bars to thirty inches long with fifteen brake bars. Finally, most people concluded that a rack about fourteen inches long with six commercial brake bars was best. Besides the inconvenience of their length that makes them just too long to fit into most side packs, racks have one terrible shortcoming--they are too weak.

While the principle of operation of the super rack is identical to that of a standard rack, we feel it is far superior. With a regular rack the amount of friction applied to the rope by the brake bars was varied by changing the distance separating the bars. This changed the angle of the rope between the bars and to a minute degree the actual distance the rope was in contact with the bars. When the desired amount of friction could not be obtained by varying the spacing of the bars being used, another bar either had to be added or removed thereby significantly changing the contact area between the rope and the bars. This was not only inconvenient but sometimes dangerous. Many times people would find themselves moving at such speeds that it would be impossible for them to achieve the control of descent necessary to add another bar. This resulted in many minor physical and major psychological injuries. In order to avoid this dangerous situation many users of the rappel rack started the descent with five or six bars already on the rope and feed the rope through the rach inch by inch, sometimes for several hundred feet. This was an extremely exhausting procedure.

Another very annoying and potentially dangerous problem with standard racks is the pinching together of the top two brake bars.This causes tremendous overheating and usually increases friction to the point where hand feeding of the rope is necessary. If the condition persists for very many feet it often becomes irreversible. The second bar becomes so hot that even with gloves the rappeler cannot hold it long or tightly enough to separate it sufficiently from the top bar to alleviate the situation. Then it becomes necessary to either hand feed the rope for extended periods of time or remove bars until comfortable rappelling is achieved. If the latter is chosen sometimes the friction between the tope two bars suddenly decreases and the individual find himself going out of control.

While the proper use of the rappel rack has been achieved by many people, the majority of users will go to almost any length to avoid adding or removing bars while in actual rappel. One basic idea behind the rack was to allow the individual using it to change the number of bars in contact with the rope while rappelling. In order to incorporate this feature, racks were designed with one open side,which allowed the user to easily pass the rope back and forth while changing the number of bars in use. This was unfortunately the very thing that caused the rack to be terribly deficient in strength.

The super rack has been designed with safety, convenience, and durability in mind. With is the user never has to change the number of bars in contact with the rope. Four is all there are, and all that are needed. Due to the size of the bars, the use of spacers between the first and second bars, and the provision for emergency stopping with the two extended top posts, the friction between the bars and the rope can be varied tremendously. With standard racks, people often begin long rappels with four bars and addone or in rare instances two more bars before reaching bottom. With the super rack four bars are used at all times. At the start of the rappel the lower two bars are held in the hand to maintain spacing as per usual rack procedure, with the built in spacers eliminating the constant nuisance of the top two bars jamming together. As the rappel progresses the lower two bars can be easily moved up and down to provide precise control of rappel speed. Within about one hundred feet of bottom the rappel is easily controlled by moving only the bottom bar and it is not necessary to hold the free end of the rope at all. If for some reason it is desirable to come to a sudden stop, it is easily accomplished by simply lifting the free part of the rope as it exits from the lower end of the rack and bring it over the top of the rack between the two extended posts. Then movement is completely stopped and both hands are free. To resume rappel just lift the rope back off the top and let it drop back to normal position.

Although the large bars provide more than adequate friction to stop an individual during rappel, we found that they can be spaced far enough apart so that with one hundred pounds suspended on the free end of the rope it is as easy to rappel as with a standard rack using four bars under the same conditions. The primary consideration however with all equipment is not convenience but safety.

Most commercially available equipment is safe if used by careful people under ideal conditions. However, since many cavers are not careful, and sometimes unexpected things happen to even the most conscientious people, all items of caving equipment should have a large safety factor. Because vertical caving has such a high risk involved., equipment used for this particular facet of spelunking should have the highest possible safety margin. Ropes, webbing, carabiner, and ascenders have constantly been modified and improved over the years to increase their strength and durability. Unfortunately, rappel devices have not followed suit. Modern racks bend at very low load levels to such an extent that the bars become immovable and the adding or removal of additional bars is impossible. Even the now condemned single carabiner brake has higher strength before failure than a standard rack has before becoming a twisted piece of useless metal. The number of fatalities and serious accidents due to single brake bar failures is frightening, and they have a strength of around 1700 pounds. Most racks begin to undergo deformation far below 1600 pounds, some even as low as 500 pounds! While permanent deformation may not occur, the rack flexes and ceases to be functional temporarily, which can easily result in major accident. This problem is inherent in the basic design of the rappel rack. It is not the fault of the original inventor. In order to make a rappel device to meet his specifications the load had to be carried by only one side of the frame since the other side had to be open to allow the rope to pass freely through. The design also incorporated easily available commercial brake bars and was a great milestone in vertical caving technology. However, the rack has some serious disadvantages, most of which were discussed elsewhere in this article. Here we will deal only with strength and heat dissipation properties.

Most racks are designed to use commercial brake bars. However, round commercial brake bars have slightly varying strength depending on the alloy used and different amounts of aluminum behind the hole and notch. The weakest point of a brake bar is the small area between the notch and the top. Bars which are drilled in the center have only 0.11 sq. in. of material behind that notch! In the bars which are drilled off center the area is only 0.15 sq. in. The rectangular bars which were available had only 20% greater area. Blue Water Ltd., is marketing bars especially for their racks which are made of an extremely high strength aluminum alloy. The problem, however with all the very high strength aluminum alloys, including those regularly used for brake bars, is that they have a low coefficient of thermal conductivity. The scale goes from 0.28 - 0.52 CGS units (excluding special electrical conducting grades) for wrought aluminum alloys with the very high strength alloys being 0.28 - 0.35 on the scale. The alloy used in the super rack bars has a value of 0.40 CGS units. (CGS units = $cal/cm/cm^2/^oC/sec$).

Heat dissipation is a major problem facing people doing the pits of 400,600,1000., and even 1500 feet that we have today. This factor and height were the major founding reasons behind the hollow brake bars that were on the market for awhile. The problem was that on really long drops they didn't work. While they had large areas in contact with the air, they lacked mass and necessary contact area with the rack frame. Also if one were to wear through the wall to the open area during rappel, the sharp edges formed could be disastrous to the rope. I included values for a hollow bar rack in the table concerning heat dissipation to show their relative merits and drawbacks.

It is in the area of heat dissipation that the super rack has shown its most obvious advantages. It dissipates heat faster to the frame and the air than any commercial rack, and also has the mass of aluminum in the bars necessary to act as a heat sink. The aluminum spacers between the top and second bars not only keep the upper bars from pinching together and overheating, but also acts as heat transfer links between them and help maintain the temperature equilibrium of the super rack. Under normal rappel conditions (e.g., fairly clean rope, reasonable spped) the tope three bars of the rack maintain almost equal temperature with the bottom bar being cooler. In actual field tests ar Fern and Ellison's, two people of similar weight rappelled side by side on two ropes as identical as possible at the same speed. On reaching the bottom, the regular rack bars were so hot they could barely be held with gloves but the super rack bars were only warm to touch with bare hands

Here in Parkersburg, we have been using super racks for over a year and they have proven reliable in all the major pits of West Virginia as well as numerous others in Virginia, Kentucky, Georgia and Alabama. They have also been used at Stone Mountain and on many other cliffs. No one has ever had control problems using a super rack or had one overheat.

Upon first examination of the drawing of the super rack most people are concerned about the strength of the threads and nuts used to hold it together. The threads and nuts are actually stronger than the rod itself used to make the frame. Machinists have known for years that bolts and the matching nuts sold to fit them are designed so that the threaded portion in the nut is actually stronger than the bolt itself. The super rack frame was designed for optimum strength, the weakest part of it is actually the unused portion of the threaded section of the rod not in the nuts. The theoretical minimum strength of the rod at this point is 9,350 pounds! (for those who doubt the strength we attempted to test it). The rack is held together by two threaded end with two nuts on each end. We used a large hydraulic press and built a jig to tensile test bolts. The ones we tested had only on nut on the end. They broke at 17,500 pounds, over 8½ tons!!, sending pieces of shrapnel flying everywhere. The bolts tested were type 316 stainless steel. The super rack frame is type 304 which is even stronger! A super rack has never been broken because it is so much stronger than any other piece of vertical caving equipment available. Besides, if you were hit with shrapnel from a falling piece of metal under at least 10,000 pounds pressure there would be nothing left but a hole where it went through. According to previous testing, (see Stiles, Destruction Testing of the Rappel Rack, NSS News Vol. 29 No. 10,) even the strongest racks with welded eyes (which increases the strength tremendously) fail below 3200 pounds. This shows the super rack frame to be 585% stronger than that of the best existing racks! Super racks have been tested to 2000 pounds with no temporary or permanent deformation.

A major advantage of the frame is that the load is carried evenly by both sides of the rack. This eliminates the tendency to twist and spring which causes the regular rack to bind the brake bars and make them immovable. Also the design with an open end on top allows the use of specially designed brake bars. The super rack has four bars all of which are cut differently depending on their position. All are of one inch square extruded bar stock, but are relieved differently for the rope and only two are slotted to open. Due to their size and the alloy the brake bars on the super rack have a minimum theoretical strength of 9,100 pounds. That is over 545% stronger than standard commercial brake bars!

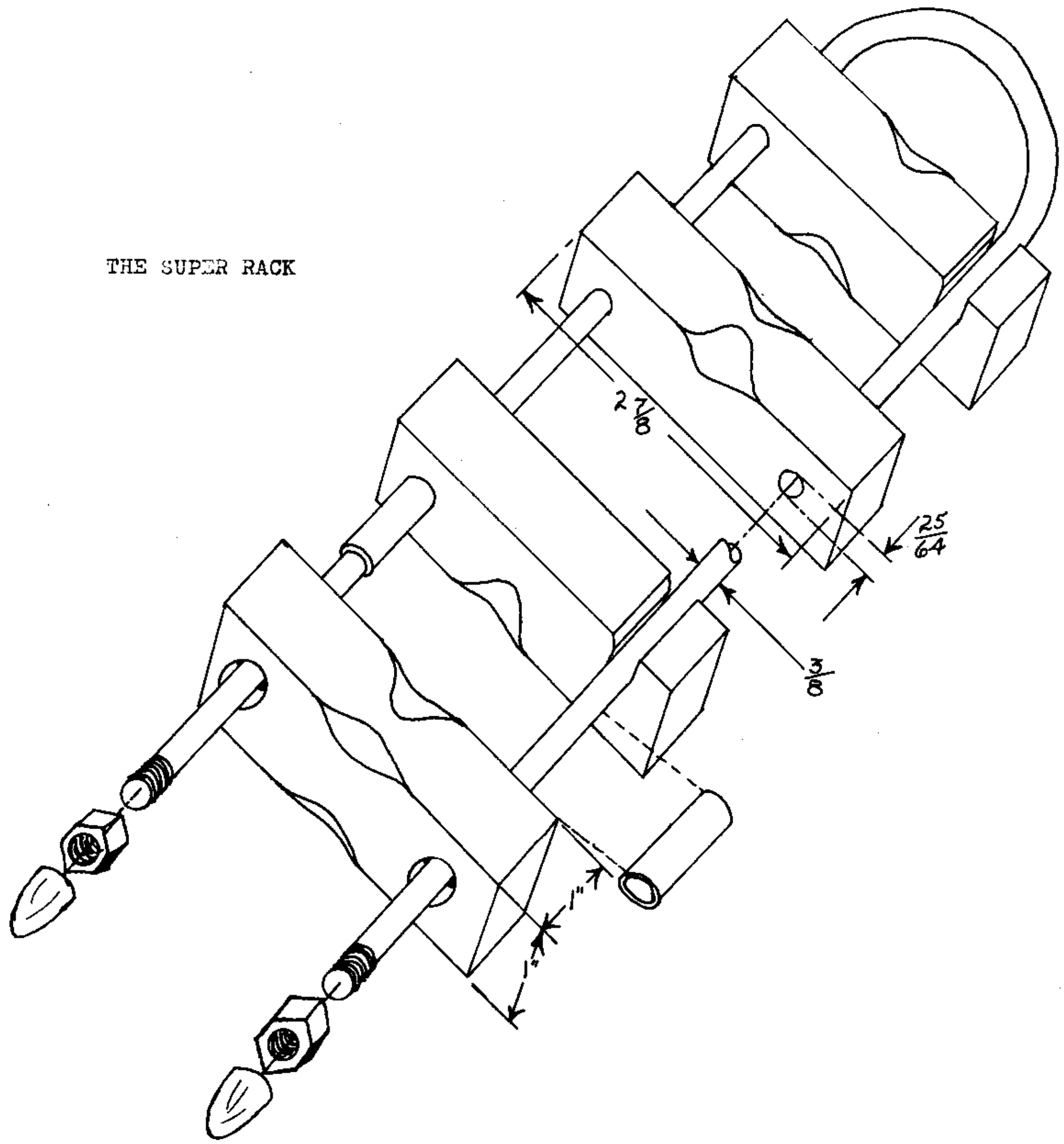
The strength of the super rack is so high that its failure due to forces generated during rappel would be unbelievable. No human could stand the forces of over 9,000 pounds necessary to cause failure of a bar. In addition to that, no rope in use has anywhere near that strength, webbing would snap like thread, and pieces of carabiners would be everywhere! A drawing of the new rack accompanies this article along with a table of values affecting heat dissipation calculated using round commercial bars on standard racks.

While standard racks have very limited uses, besides being the best rappel device available anywhere the super rack has numerous other uses. I have used mine to drive pitons, as an equalizer during heated discussions, as a jam nut while rock climbing, for driving tent stakes, and even as a tow bar to pull cars with! It is a useful, indestructable, and invaluable piece of caving equipment. Besides all its other advantages, the rack is under twelve inches long and fits easily into a side pack. Custom built super racks are available in limited quanities from the author at $15.00 each.

Super Rack

References:
American Iron and Steel Institute (AISI) Steel Products Manual Machinery's Handbook, by Oberg &Jones
Industrial Press Aluminum Handbook, Aluminum Company of America.
Handbook of Chemistry and Physics, Chemical Rubber Company
Destruction Testing of the Rappel Rack, Stiles, NSS News, Vol. 29 No. 10.
Strength data for ropes, carabiners and webbing from manufacturers.
Some of the designing and most of the actual machine work required to build the original super rack was performed by D. C. Province, who also provided invaluable assistance during field testing.

THE SUPER RACK



PHYSICAL PROPERTIES AFFECTING HEAT DISSIPATION OF VARIOUS RACKS

	RACK WITH SIX HOLLOW COMMERCIAL BARS	RACK WITH FIVE SOLID COMMERCIAL BARS	RACK WITH SIX SOLID COMMERCIAL BARS	SUPER RACH WITH FOUR SOLID ONE INCH SQUARE BARS	SUPER RACK VALUES COMPARED TO THOSE OF A RACK WITH SIX SOLID COMMERCIAL BARS
TOTAL SURFACE AREA OF BARS IN CONTACT WITH AIR	69.60 sq. in.	35.4 sq. in.	42.2 sq. in.	52.00 sq. in. *	123%
TOTAL VOLUME OF ALUMINUM IN BARS	3.03 cu. in.	5.80 cu. in	6.96 cu. in	11.00 cu. in	158%
TOTAL WEIGHT OF ALUMINUM IN BARS	3.4 oz.	6.5 oz.	7.8 Oz.	16.5 oz.	212%
TOTAL SURFACE AREA OF BARS IN CONTACT WITH RACK FRAME	1.32 sq. in.	4.55 sq. in.	5.46 sq. in.	4.72 sq. in. **	86%

* By adding the outside area of the two spacers which also dissipate heat the super rack has a total surface area in contact with the air of 55.09 sq. in.

** By adding the inside area of the two spacers which also dissipate heat the super rack has a total surface area in contact with the rack frame of 6.58 sq. in.