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THE WISCONSIN ENGINEER

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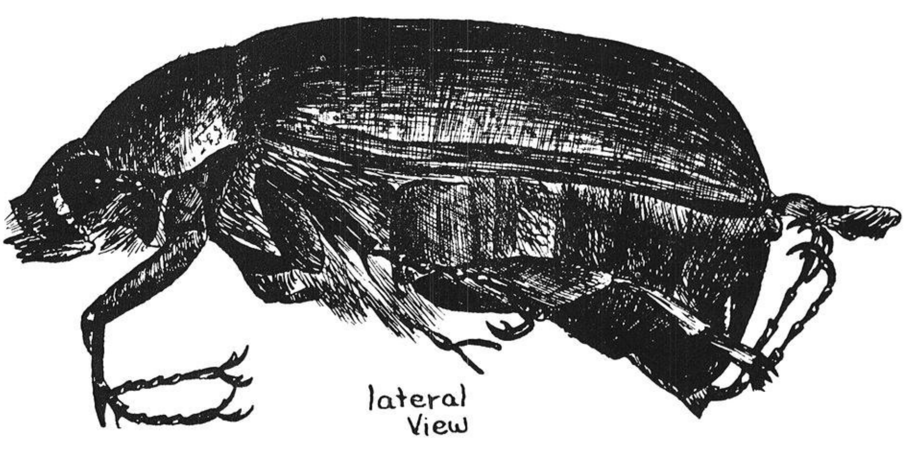

Phyllophaga rugosa

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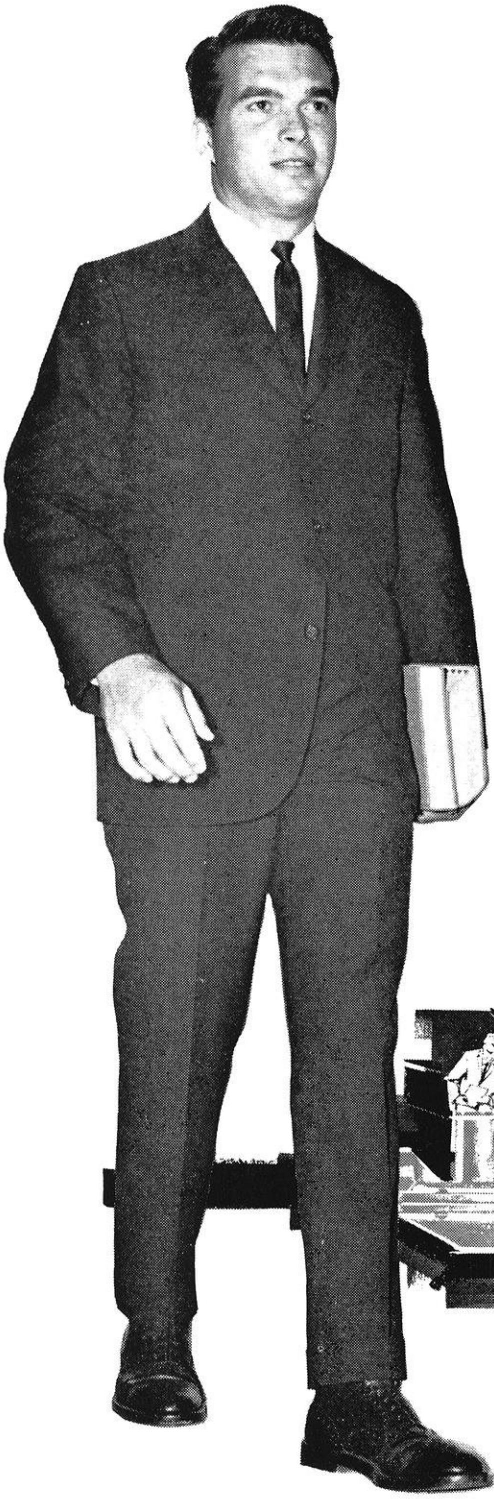

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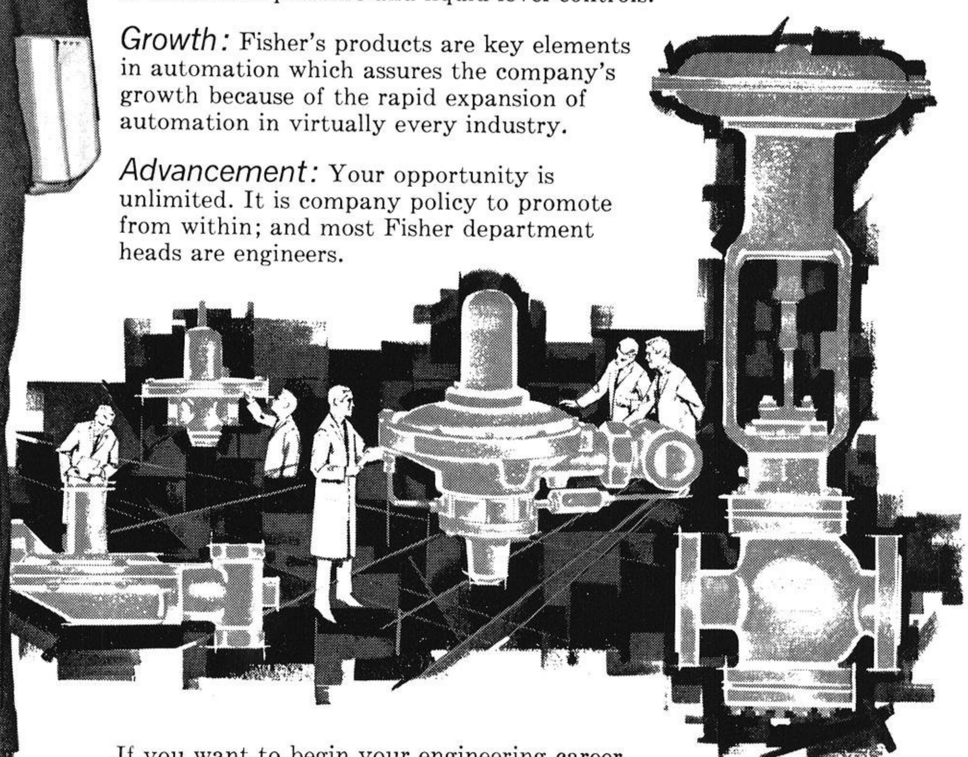

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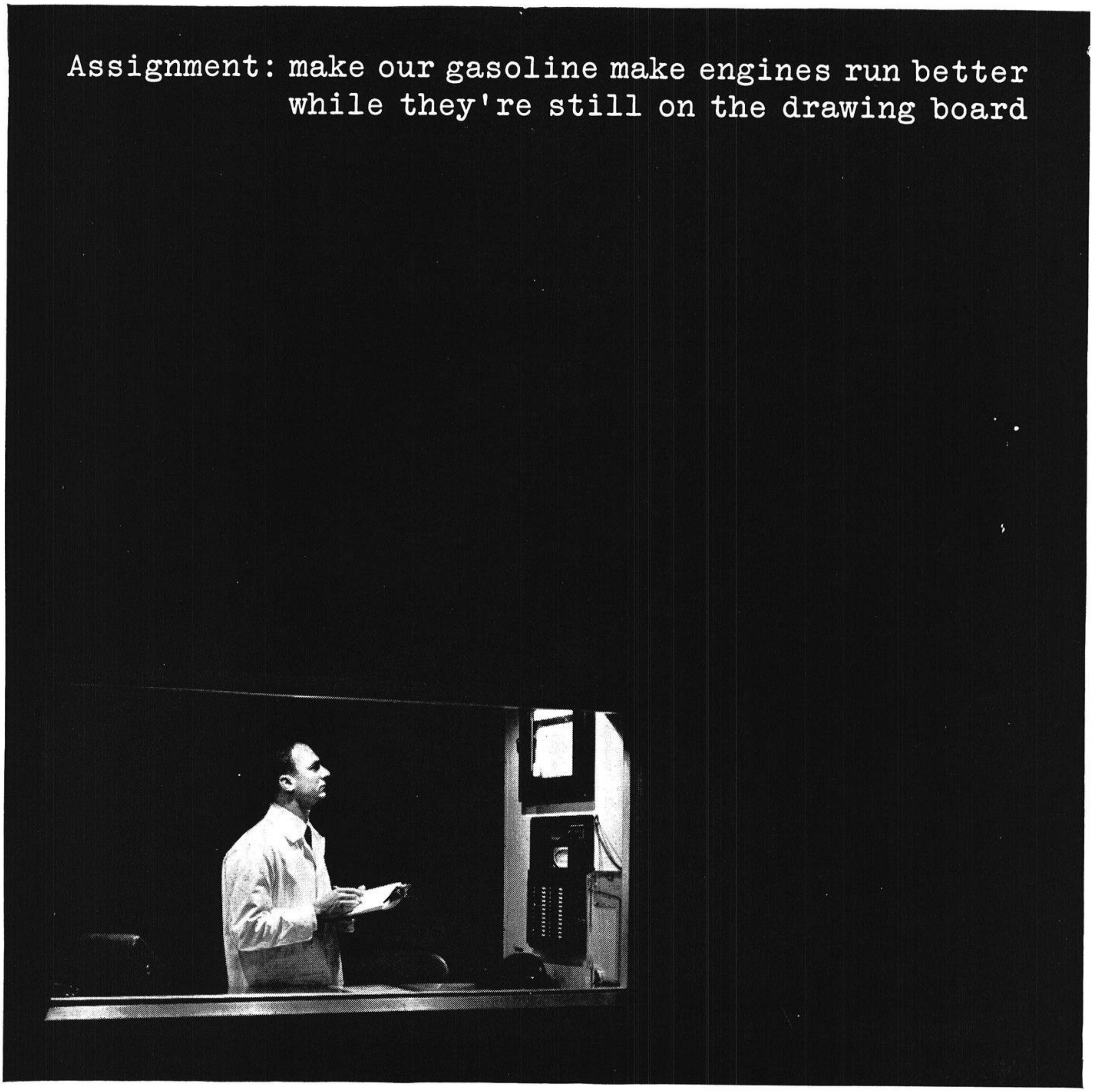

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ARTICLES

THE WISCONSIN ENGINEER

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Rambling With The Editor

CANONS OF ETHICS FOR ENGINEERS

In place of an editorial this month canons of ethics for engineers will be published in full

FOREWORD

Honesty, justice, and courtesy form a moral philosophy which, associated with mutual interest among men, constitutes the foundation of ethics. The engineer should recognize such a standard not in passive observance, but as a set of dynamic principles guiding his conduct and way of life. It is his duty to practice his profession according to these Canons of Ethics.

As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers, and clients, and with fairness and impartiality to all. It is his duty to interest himself in public welfare, and to be ready to apply his special knowledge for the benefits of mankind. He should uphold the honor and dignity of his profession and also avoid association with any enterprise of questionable character. In his dealings with fellow engineers he should be fair and tolerant.

PROFESSIONAL LIFE

SEC. 1. The engineer will co-operate in extending the effectiveness of the engineering profession by interchanging information and experience with other engineers and students and by contributing to the work of engineering societies, schools, and the scientific and engineering press.

SEC. 2. He will not advertise his work or merit in a self-laudatory manner, and he will avoid all conduct or practice likely to discredit or do injury to the dignity and honor of his profession.

RELATIONS WITH THE PUBLIC

SEC. 3. The engineer will endeavor to extend public knowledge of engineering, and will discourage the spreading of untrue, unfair, and exaggerated statements regarding engineering.

SEC. 4. He will have due regard for the safety of life and health of the public and employees who may be affected by the work for which he is responsible.

SEC. 5. He will express an opinion only when it is founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission, or other tribunal.

SEC. 6. He will not issue ex parte statements, criticisms, or arguments on matters connected with public policy which are inspired or paid for by private interests, unless he indicates on whose behalf he is making the statement.

SEC. 7. He will refrain from expressing publicly an opinion on an engineering subject unless he is informed as to the facts relating thereto.

RELATIONS WITH CLIENTS AND EMPLOYERS

SEC. 8. The engineer will act in professional matters for each client or employer as a faithful agent or trustee.

SEC. 9. He will act with fairness and justice between his client or employer and the contractor when dealing with contracts.

SEC. 10. He will make his status clear to his client or employer before undertaking an engagement if he may be called upon to decide on the use of inventions, apparatus, or any other thing in which he may have a financial interest.

SEC. 11. He will guard against conditions that are dangerous or threatening to life, limb, or property on work for which he is responsible, or if he is not responsible, will promptly call such conditions to the attention of those who are responsible.

SEC. 12. He will present clearly the consequences to be expected from deviations proposed if his engineering judgment is overruled by nontechnical authority in cases where he is responsible for the technical adequacy of engineering work.

SEC. 13. He will engage, or advise his client or employer to engage, and he will co-operate with, other experts and specialists whenever the client's or employer's interests are best served by such service.

SEC. 14. He will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

SEC. 15. He will not accept compensation, financial or otherwise, from more than one interested party for the same service, or for services pertaining to the same work, without the consent of all interested parties.

SEC. 16. He will not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with his client or employer in connection with work for which he is responsible.

SEC. 17. He will not be financially interested in the bids as or of a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client or employer.

SEC. 18. He will promptly disclose to his client or employer any interest in a business which may compete with or affect the business of his client or employer. He will not allow an interest in any business to affect his decision regarding engineering work for which he is employed, or which he may be called upon to perform.

RELATIONS WITH ENGINEERS

SEC. 19. The engineer will endeavor to protect the engineering profession collectively and individually from misrepresentation and misunderstanding.

SEC. 20. He will take care that credit for engineering work is given to those to whom credit is properly due.

SEC. 21. He will uphold the principle of appropriate and adequate compensation for those engaged in engineering work, including those in subordinate capacities, as being in the public interest and maintaining the standards of the profession.

SEC. 22. He will endeavor to provide opportunity for the professional development and advancement of engineers in his employ.

SEC. 23. He will not directly or indirectly injure the professional reputation, prospects, or practice of another engineer. However, if he considers that an engineer is guilty of unethical, illegal, or unfair practice, he will present the information to the proper authority for action.

SEC. 24. He will exercise due restraint in criticizing another engineer's work in public, recognizing the fact that the engineering societies and the engineering press provide the proper forum for technical discussions and criticism.

SEC. 25. He will not try to supplant another engineer in a particular employment after becoming aware that definite steps have been taken toward the other's employment.

SEC. 26. He will not compete with another engineer on the basis of charges for work by underbidding, through reducing his normal fees after having been informed of the charges named by the other.

SEC. 27. He will not use the advantages of a salaried position to compete unfairly with another engineer.

SEC. 28. He will not become associated in responsibility for work with engineers who do not conform to ethical practices.

The Flight System of Phyllophaga Rugosa

By James K. Lawton

Jim Lawton is a senior majoring in entomology. His article is the result of his own original research. The cover illustration and the illustrations in the article were drawn by the author. After graduation he plans to work in the field of biological control of insects.

THE following paper will be devoted entirely to the mechanism of flight of *Phyllophaga rugosa*. The majority of the article will cover the complete morphological system behind its flight and a brief section covering the factors of flight itself.

External Morphology

First of all, the external morphological characteristics need mentioning before we go into the body cavity. The cover shows the lateral and dorsal view of the species. The length of the species is about 22 mm and its general form is oblong, slightly dilated posteriorly. A rather well description of the insect was presented in *A Manual of Common Beetles of Eastern North America* by Dillon and Dillon and is quoted as follows:

"Oblong, rather robust, broader posteriorly; reddish brown to piceous, shining. Clypeus acutely, rather deeply emarginate anteriorly; margin scarcely reflexed anteriorly; surface densely and rather coarsely punctuate, the front more coarsely so. Pronotum widest at middle; sides obtusely angulate, distinctly narrowed at base, more obliquely narrowed in front; basal margin broadly, shallowly depressed at middle of each side; disk coarsely and deeply punctate, punctures irregularly and moderately closely placed, median line raised. Elytra more finely and densely punctate than pronotum, somewhat finely rugose near suture, sides and apex smoother; costae of disk moderately distinct. Metasternum with rather dense, long hairs. Male with last abdominal sternite triangularly emarginate at apex and with a broad transverse, oval impression medially; next to last truncate medially at apex, with an arcuate ridge each side followed by a flattened area."

The thoracic region is the site of all the flight organs. This includes the external and internal skeleton, the direct and indirect musculature system which operate the wings, and the wings themselves which are the lateral folds of the tergal margins. And it was found that in the June beetle, this whole system had been greatly modified through the evolutionary trend from that of the primitive or the generalized insect.

The General Thorax

Looking directly at the thoracic region, the whole body wall is greatly and heavily scleritised to accommodate the flight mechanism. There it was found that much fusion of the individual sclerites found in simpler insects had occurred, and this scleritization was much thicker. This body wall is a part of the insect's skeletal system (the external skeleton) which accommodates the strong internal muscle attachments. In my estimation this body wall development is much needed for the species because the insect's body is especially heavy, and as will be mentioned later only one pair of wings do the actual work needed to carry that weight. And this greater scleritization gives its muscle attachment even greater strength. However, the body wall is divided by sutures to allow some movement and flexibility. If the body wall were weak and the individual sclerites were separated by membranous tissue as is found in simpler insects, one can already see that the whole flying mechanism would be much less efficient and not as strong.

The Prothorax

The prothorax is very small in comparison with the other metameres in the thorax. This metamere has very little with flight; its main function is to accommodate the fore pair of walking legs and to house the digestive organs. It

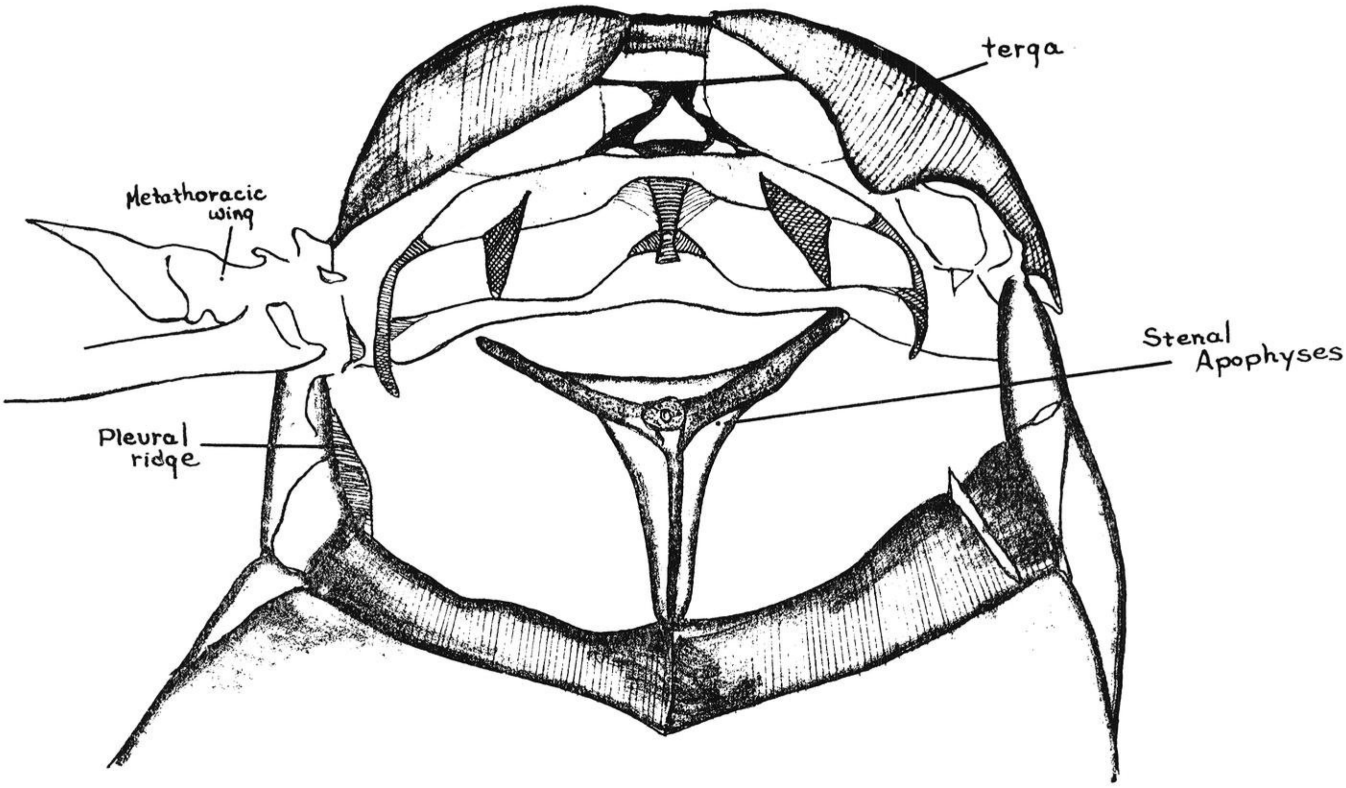


Plate 2 - Cross Section of Thorax showing Development of Internal Skeleton

lies directly behind the head and just anterior to the mesothorax. The attachment of this metamere to the pterothorax (the two wing bearing metameres or the meso and metathorax) is very weak and loosely connected; much unlike the rest of the thorax which is highly fused together. This also confirms the theory that the prothorax does not have any real function in flight. In fact, in my dissections, the prothorax could be easily pulled off from the pterothorax. It is almost like a completely different body region; so unlike the rest of the thorax.

The Mesothorax

The mesothorax is the region of the thorax lying between the prothorax and the metathorax. This is the fore metamere of the fused pterothorax. It accommodates the fore pair of wings. Because this pair of wings are entirely scleritised, it has little to do in aiding flight. Further discussion on this pair of wings will take place later, but the important fact is that because of this non-flight function its primary muscle attachment is small and the muscles themselves are few and small. Hence the cavity in this metamere is very small in comparison with the metathorax. You might even say that its more important function is to control its pair of walking legs.

The Metathorax

However, in the metathorax, this metamere is the largest of the pterothorax and even in the whole thoracic region. It is the posterior region of the pterothorax and lies directly behind the mesothorax and anterior to the abdomen. The main flight mechanism centers in this region for the only pair of membranous wings originate from it. Because of this, the body cavity needed to house all the large flight muscles is very large. The whole region is very complex in development, especially with its internal skeletal system, which will be discussed below.

The one thing to remember is that the meso and metathorax are greatly fused together making it appear as though the two regions were as one. Of course, the knowledge that only one pair of wings can originate from only one metamere tells us differently and the sight of the internal structure proves it beyond a doubt. This fused condition allows for a stronger skeletal structure upon which much stress is applied during flight.

When the insect is at rest the meso and metathorax lie beneath the covering of the hardened mesothoracic wing of "elytra" as the cover shows while the exposed prothorax lies anterior to it.

The Internal Skeletal System

Upon dissection of the thoracic region and with the clearing away of the entire muscle system, you immediately expose the internal skeletal system. In this particular insect this internal development has been highly evolved and is very complex. It is known that the internal skeletal system allows for more muscle attachment and greater strength. And because this insect needs all the strength it can get to allow the pair of wings to carry its heavy body, the internal

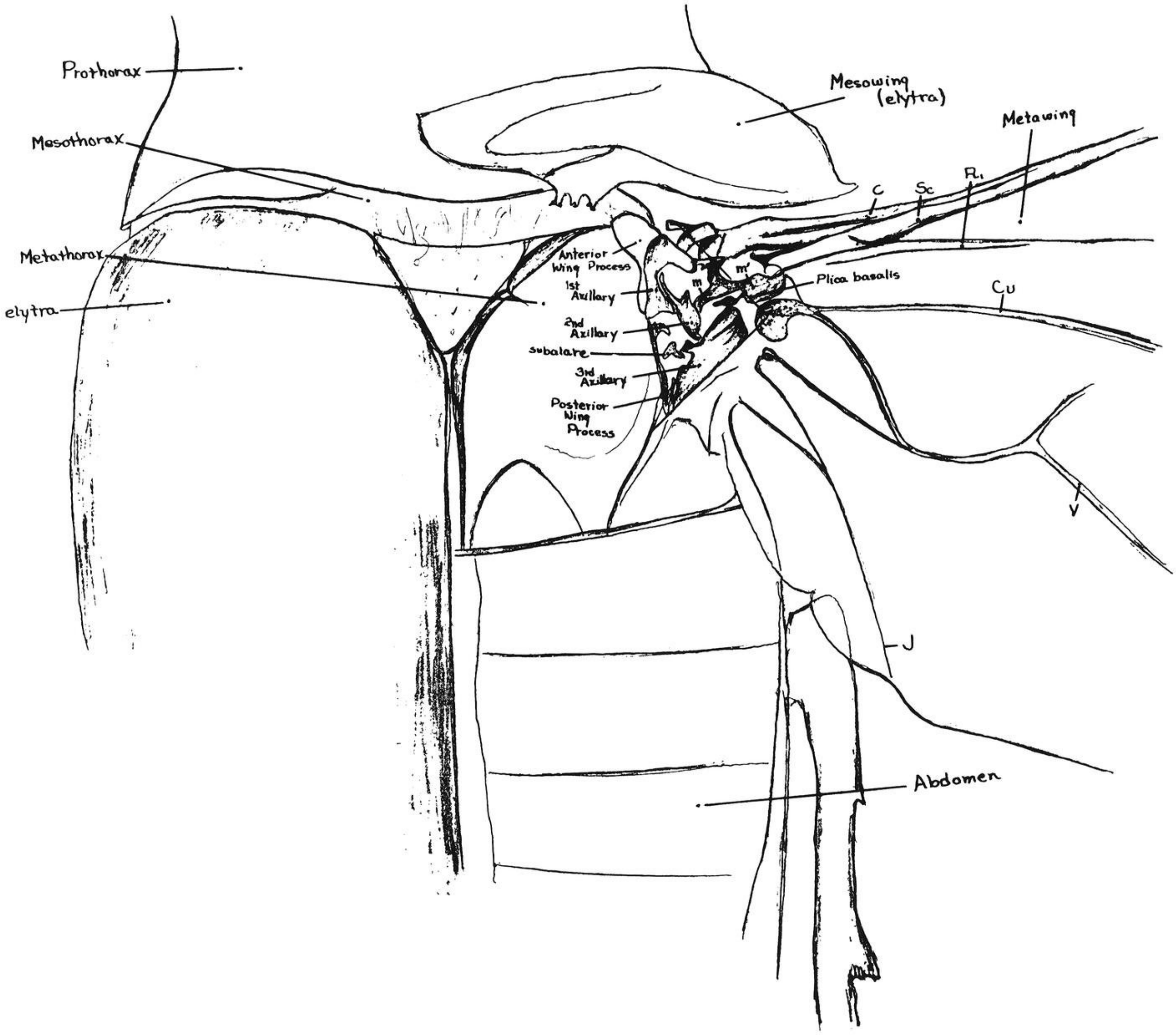


Plate 3 - Bases of Fore and Hind Wings (Dorsal View)

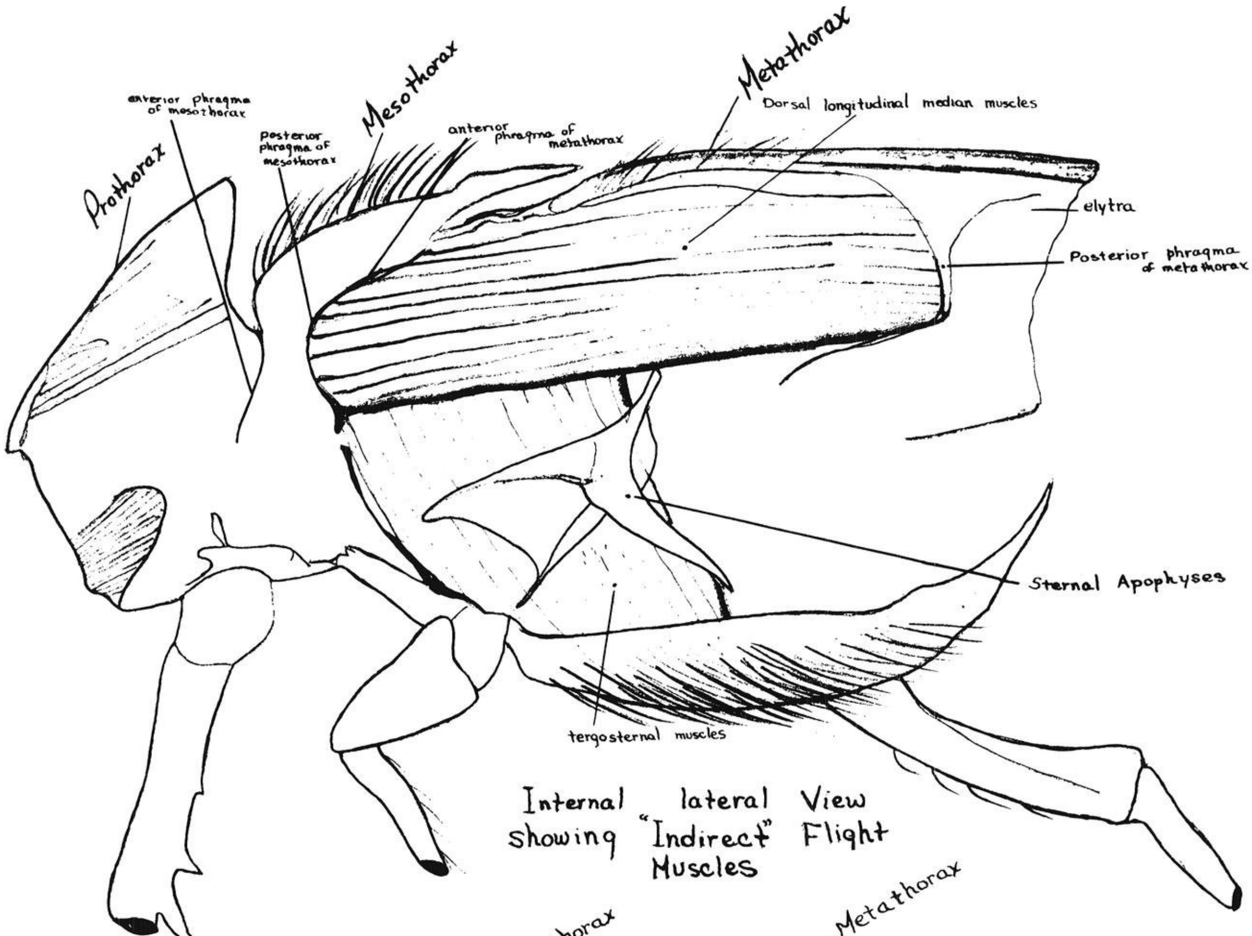
skeleton is large and heavily built up.

The forces exerted by the flight muscles are considerable. Therefore, this elaborate system is needed to avoid wasting energy in the buckling of the thoracic walls caused by the muscle action.

The internal skeleton is produced by interal folding of the body wall. Plate 2 shows this in some detail. The dorsal wall shows the most development with less at the pleural and sternal regions. First, there are the large sclertised anterior and posterior phragmas (prephragma and postphragma) needed for considerable muscle attachment. See plate 4. Then there are the dorsal and pleural infoldings or ridges which help stiffen the body wall. The dorsal infoldings occupy practically the whole dorsal region of the body extending down as far as the pleural region. *In the pleural region it is interesting to note that this region is stiffened against compression in a dorso-ventral direction by the scleritised fold which forces the pleural wing process laterad by outward tergal movement during the downstroke; being resisted by the brace composed of the pleural ridge, the sternal apophysis, and an associated muscle.* The pleural ridge hence acts to support the body wall and as a pivot or fulcrum upon which the wing pivots. I might add here that in this species, the pleural ridge is very small—being aided by the heavy development in the tergal area. This sternal apophysis is the sternal infolding forming a furca. It acts like a bridge connecting with the pleural ridge via connective fibers. But again this aids in strengthening the whole body wall. By looking at Plate 2 one can see within the dorsal region that its internal skeletal system is highly modified into an inter-network of scleritised arms. The primary function of this will be seen later.

The Wing Articulation

Before going directly into the musculature system, the wing articulations must first be looked into. This articulation system is set up



Internal lateral View showing "Indirect" Flight Muscles

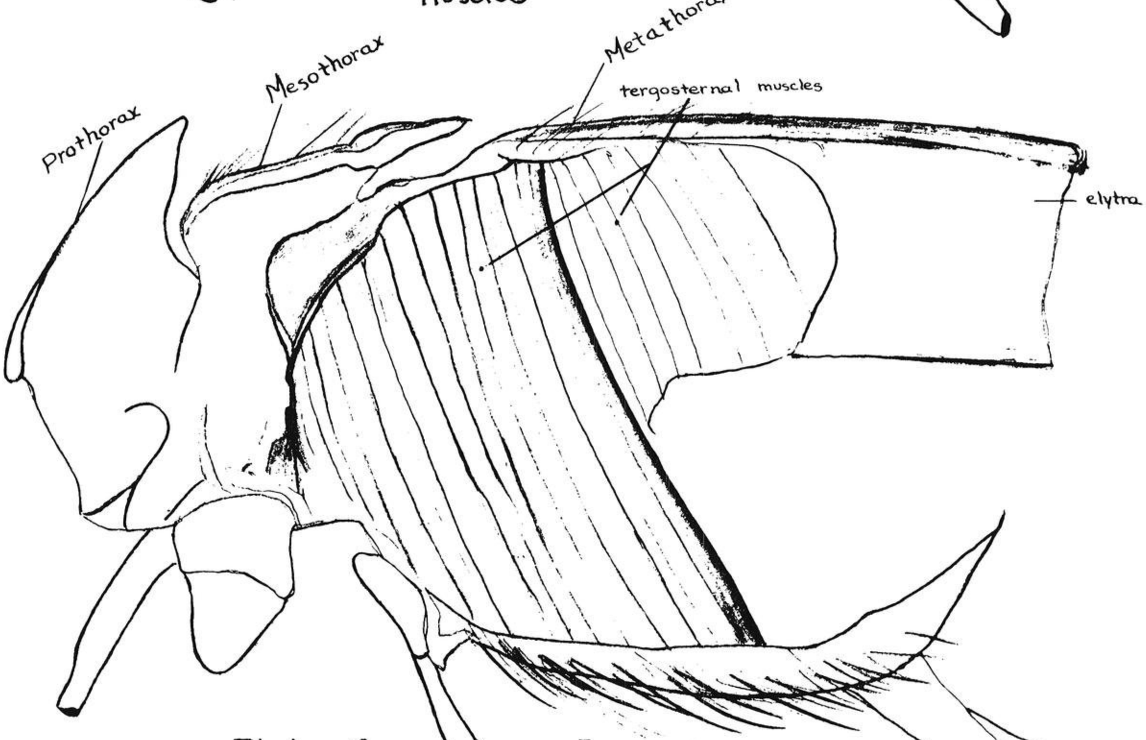


Plate 4

Internal lateral View showing Tergosternal Muscles After the Dorsals Had Been Cleared in a very complex fashion so as to allow the wing to move with greater freedom. As will be discussed later, the wing goes into a varied set of paths. This path includes a horizontal as well as a vertical one; therefore the wing must be protracted and retracted as well as elevated and depressed. Also, the angle of the wing stroke and the relative wind is variable so that there must be movements of pronation and supination to rotate the wing about its long axis.

The wing is joined to the body at the junction of both the tergum and pleuron, and a system of articulation is found at both. First of all there are the anterior and posterior notal wing processes which are "sculptured" out of the tergal margin. Between these lies the membranous emargination and within this membrane lies intricately shaped tergal sclerites at the base of the wing, each associated with a principal vein. This whole system is clearly illustrated in Plate 3.

Ventrally, as I mentioned above, the wing rests or pivots upon the pleural ridge similar to the "ball and socket joint" in its action. This support lies laterad of the tergal articulations. The wing also has a ventral connection with the basalar region anteriorly and the subalar plate posteriorly. This whole articulation system serves as important muscle attachments and plays an important role in the function of flight as will be explained later.

The Major Flight Muscles

Having now looked at the external and internal skeletal system used for support and muscle attachment, we will now discuss the musculature system itself. The muscle system used in flight consists of five sets of major muscles. These are as follows: the dorsal muscles, tergosternal or dorsoventral muscles, the axillary or flexor muscles, the basalar muscles, and the subalar muscles. Plates 4, 5, and 6 show these very well.

The tergosternal and dorsal wing muscles are usually referred to as "indirect wing muscles" while the remaining muscles, the axillary, basalar, and subalar muscles are called "direct wing muscles". It must be remembered, however, that these five sets of muscles are directly concerned with flight. There are many other muscles found in the body cavity which influence flight but to a very slight degree. Probably most of the segmental and intersegmental muscles found in the entire thorax have such a bearing. But these are so small and have so small a function that I will not discuss them.

The Dorsal Flight Muscles

First looking at the dorsal muscles: These are the longitudinal dorsal muscles of the back attaching to the large anterior and posterior phragmas. Usually the dorsal muscles are differentiated into the "median longitudinal muscles" and the "lateral oblique muscles" but all that are found in the metathorax are the median longitudinal muscles. These took up practically half of the body cavity longitudinally.

It was surprising to me that I did not find any really conspicuous dorsal muscles in the mesothorax. But it is easily seen that they would not be needed, as in the metathorax, since the mesothorax wings have no bearing in flight.

These muscles serve as wing depressors, since by their contraction, the wing bearing terga is arched upward deflecting the wings on the pleural ridge causing them to move downward. Hence, as I mentioned earlier, the terga and internal development of the skeleton have to be strong for extra support during this process. After the wings have completed the downstroke, the strength and flexibility of the dorsal wall assists greatly in forcing the wings into the upward stroke upon relaxation of the dorsal muscles. The stress upon the terga when it is arched upward is great. So as soon as the dorsal muscles relax the dorsal wall "snaps" back into normal position causing the wings to immediately rise. Plate 7 shows this process very well.

The terosternal muscles are again only found in the metathorax and not in the mesothorax for the same reason as was stated in the above. These muscles lie to the sides of the median longitudinal dorsals and in the anterior part of the metamere. Its attachment is dorsally at the anterior portion of the terga and ventrally on the basisternum before the coxae. These muscles are antagonists of the longitudinal dorsals which elevate the wings upon the pleural ridge. These muscles are greatly assisted by the elasticity of the terga as the wings are just entering the upstroke as I mentioned earlier.

Muscles Directly Involved in Flight

Looking at the direct muscles used in flight, the axillary muscle attaches directly to the wing base and arises from the lower region of the pleural ridge. There is only one axillary muscle found on each wing in the metathorax, and this muscle is very small and highly specialized over that which is found in the general insect. Because the wing has only one axillary muscle, the attachment at the wing base is directly on the third axillary. The muscle is very fibrous at this attachment. However, unlike the general insect, this fibrous tissue converges, similar to that of a cone, down to a long filamentous tough "ligament" like strand which soon is attached to the small pleural ridge. The attachment at this ridge was found to be very secure and hard to detach, hence giving much greater strength.

This muscle is the so-called flexor muscle which primarily aids in folding the wing over its back to the resting position. Its contraction revolves the third axillary dorsally and inward on the proximal wing articulations and thus turns the alar area of the wing posteriorly. It was also noted in other literature that by slightly shifting this axillary region, these muscles can alter the direction of flight.

In the mesothorax, because this metamere contains the elytra, I found no axillary muscles. There were, however, two distinct muscles on each wing to give it moveability. But because there is no axillary region or other major sclerites for muscle attachment as in the metathorax, it is difficult to homologise these muscles with that of the metawing. There will be further discussion of these muscles later.

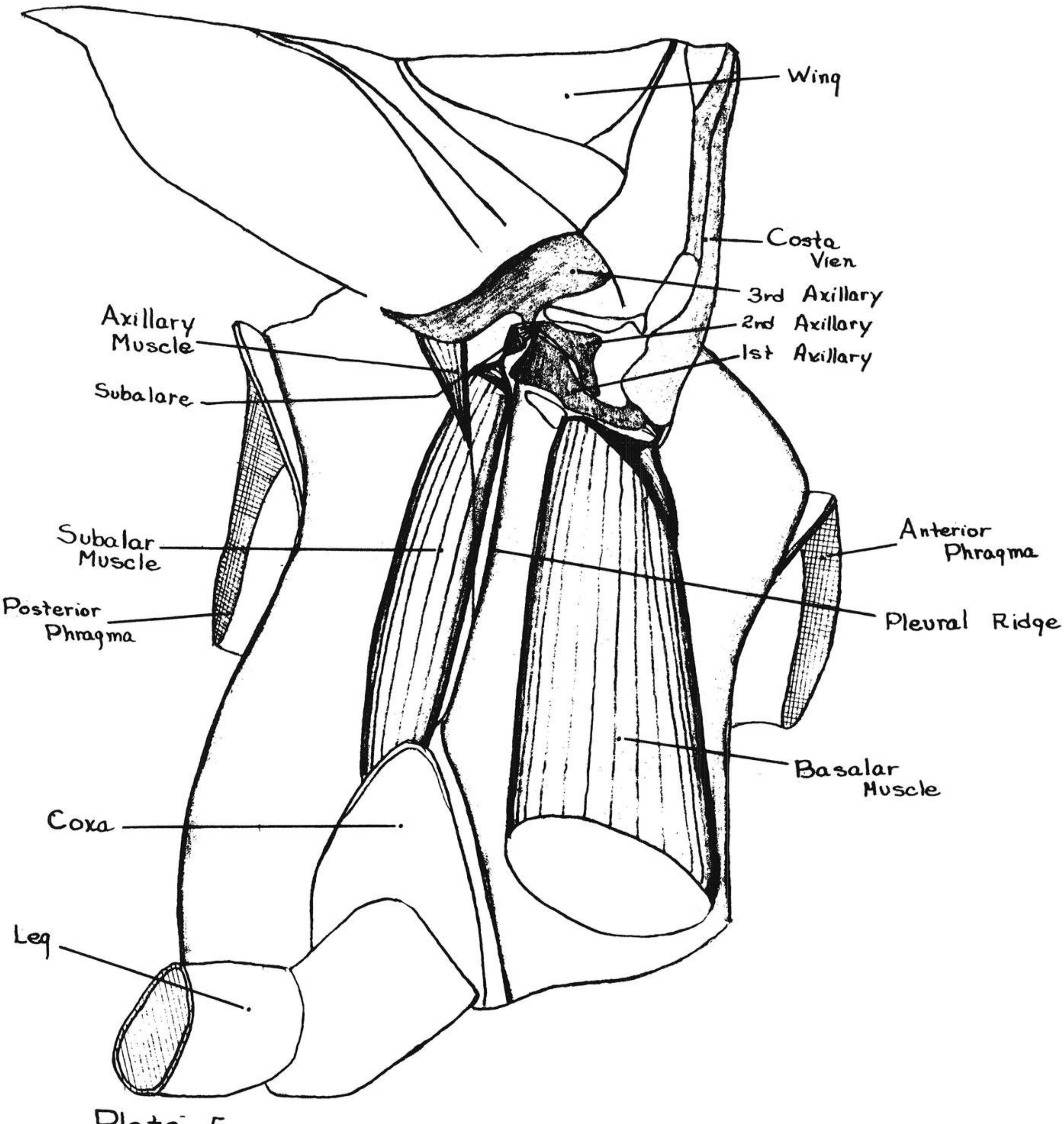


Plate 5 - lateral View of Metathorax showing the "Direct" Flight Muscles

The next and largest of the "direct flight muscles" are the basalar muscles. There is only one basalar muscle found at each metawing. Its anterior dorsal attachment is at the basalar plate of the episternum, just at and below the anterior part of the wing base, while the posterior ventral attachment is at the sternal wall just anterior to the coxal region. The muscle attachment at the wing base is again very specialized over the general insect. The muscle is inserted into a heavily scleritised but flexible pedicel like base which has a tendonous connection with the anterior axillary region of the wing. Hence, with the contraction of the basalar muscle, the costa of the wing is pulled forward and downward. This muscle is very large, being needed to cut the wing down in the power stroke with aid of the longitudinal muscles.

The third and final direct muscle found in the metathorax is the subalar muscle. Anteriorly and dorsally this muscle joins to the subalar, a region of scleritization

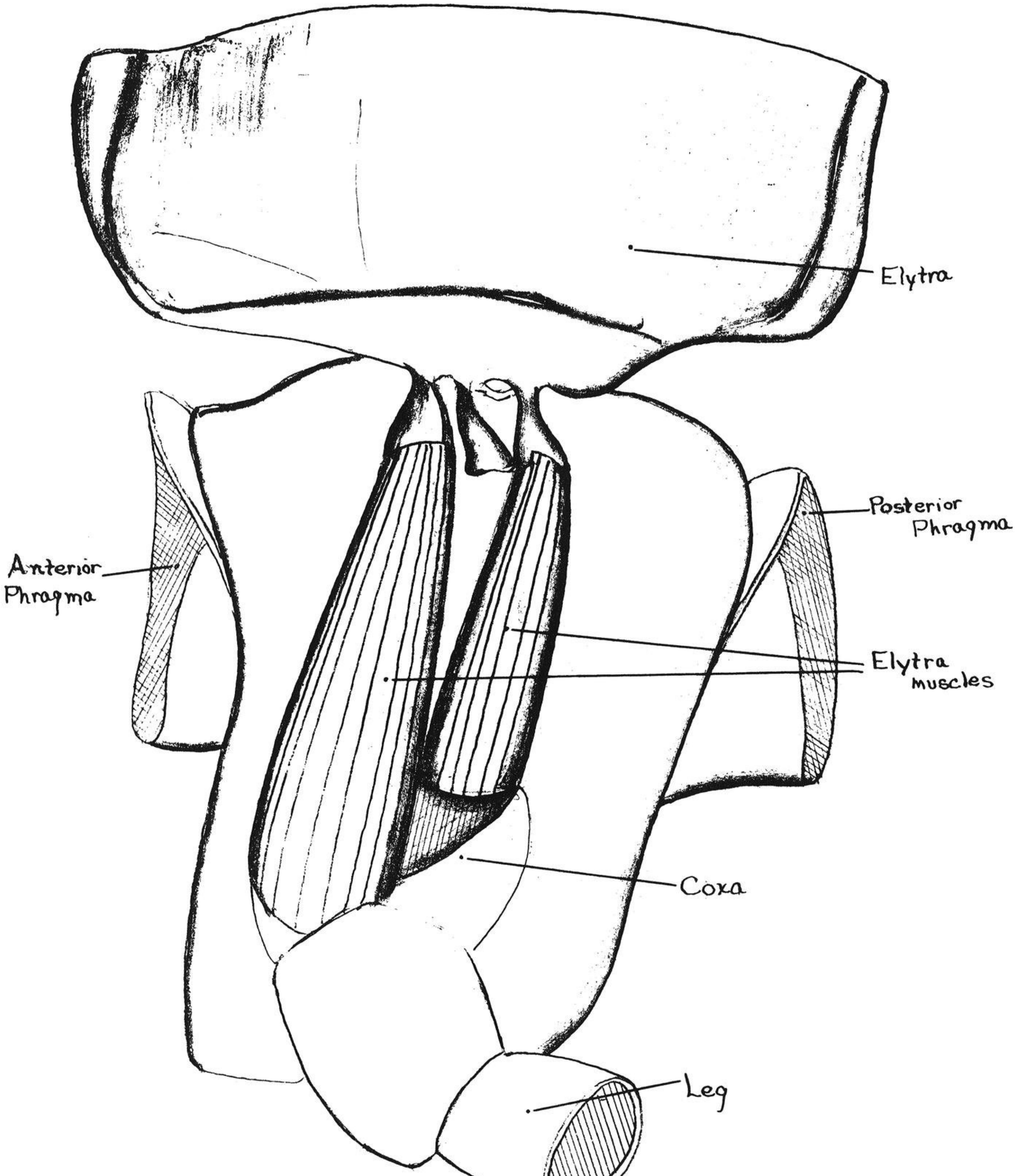


Plate 6 — lateral View of Mesothorax showing Elytra Muscles

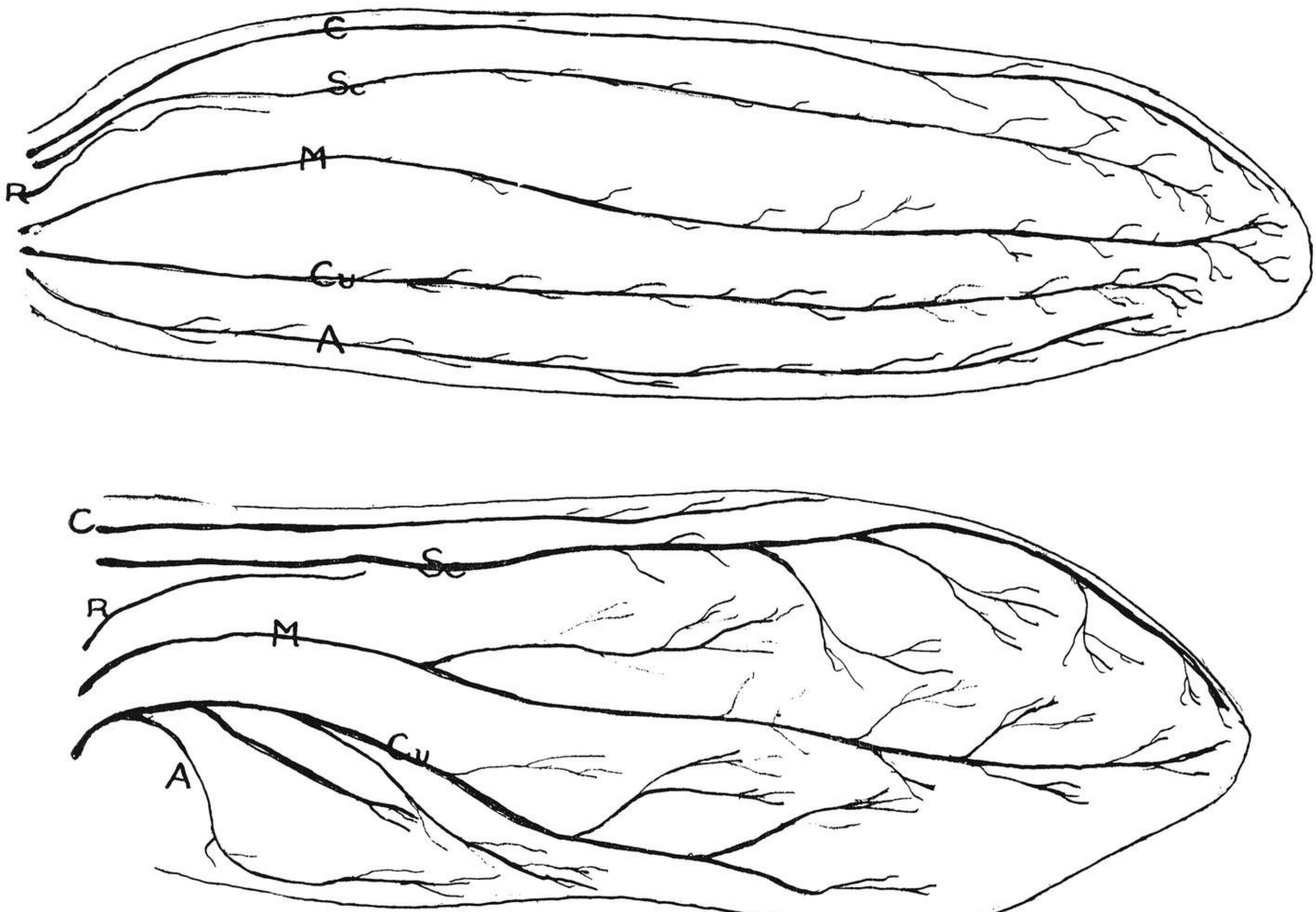


Plate 10 - Tracheation of the Wings of a Cerambycid Pupa (Comstock)

that lies in a membranous area above the epimeron and below the posterior part of the wing, while its posterior ventral attachment is on the meron of the coxa. This muscle is smaller than the basalar but larger than the axillary. Like the basalar muscle, its attachment at the wing base is a modified pedicel like joint with a tendinous attachment at the subalar. This subalar plate is directly associated with the ventral extensions of the second axillary sclerite. The contraction of this muscle depresses the vannal area of the wing and aids in spination toward the close of the downstroke.

The following table, showing the functions of the five major groups of flight muscles, was redrawn from a text titled, *Insect Physiology* by Beard, Bodenstein, etc. on "The Mechanisms of Wing Movement". This gives you a quick look at the many wing movements the five major muscles do.

Muscle Group	Location	Principal Function in Flight
1	Dorsal	Depression
2	Basalar	Depression, Protraction, Pronation
3	Subalar	Depression, Spination, Retraction
4	Dorsoventral (Tergosternal)	Elevation
5	Axillary	Flexion (retraction), Plication, Minor adjustments of the wing path

In the mesothorax, as I mentioned earlier, the muscles are considerably different. This metamere lacks both the longitudinal dorsals and the tergosternal or dorsoventral muscles. They also do not have the basalar, subalar, or axillary muscles in the true sense of the word, but do have two sets of muscles which may be modifications of the direct muscle system found in the metathorax.

The Mesowing or Elytra

The elytra is joined to the body wall by three scleritised joints or protubances. The two outer joints serve as muscle attachments, while the center joint acts as a pivot or fulcrum upon which the elytra pivots or rotates. The larger of the two muscles attach dorsally to the joint lying closest to the "costa" region of the wing. Its ventral attachment is unknown but it is suspected that it attaches to the meron of the coxa. One reason for my belief in this attachment lies in the fact that because the mesothorax is very small, the whole sternal region is occupied by the coxal area, hence, the sternal attachment would seem improbable. However, fresh specimens may dis-

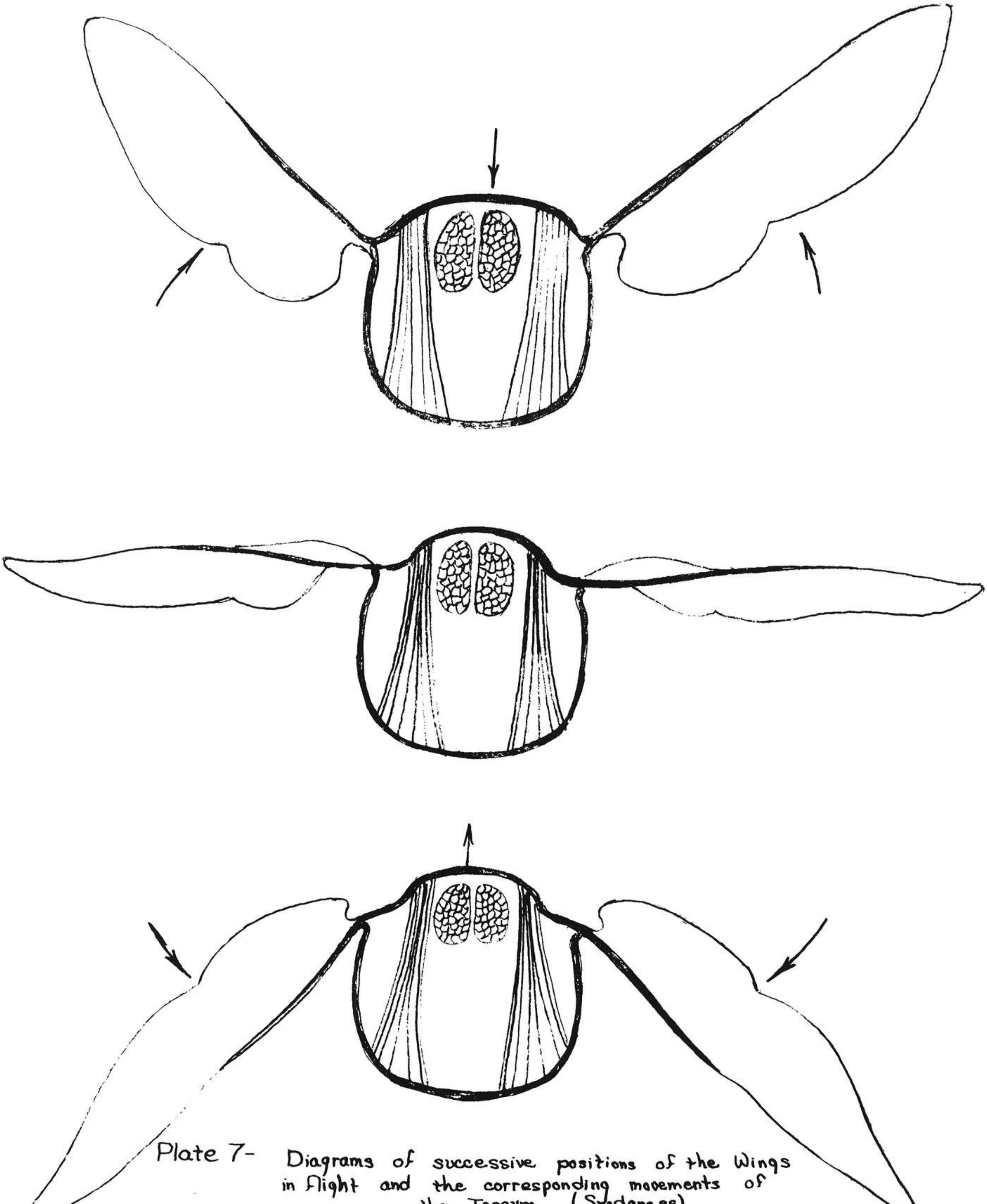


Plate 7- Diagrams of successive positions of the Wings in flight and the corresponding movements of the Tergum (Snodgrass)

prove this. The contraction of this muscle lifts the elytra up off its back, and with aid of the other elytra muscle, it holds the wing in an upward stable position while the insect is in flight. See Plate 8.

The smaller elytra muscle has its dorsal attachment at the third joint towards the posterior "vannal" area of the wing, while its ventral insertion is at the meron of the coxa. The contraction of this muscle pulls the elytra down over its back with the relaxation of the first elytra muscle. Of course it aids in stabilizing the wing during flight as was mentioned before. See Plate 6 for the muscles and their attachments. These are the only two conspicuous flight muscles that were noticeable in the mesothorax.

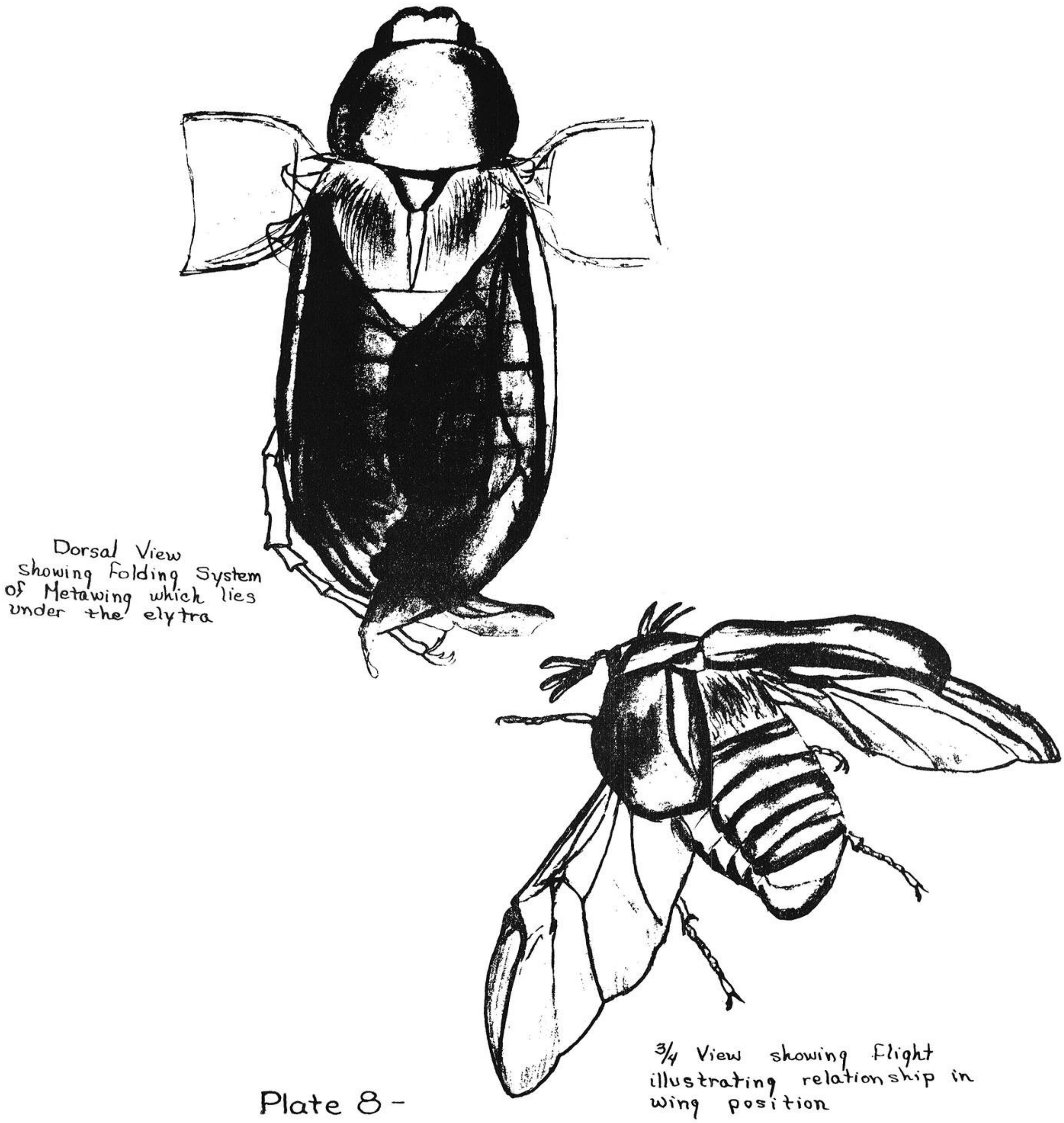


Plate 8 -

The Wing

The wings of *Phyllophaga rugosa* are highly specialized and are very unique in their structure and function.

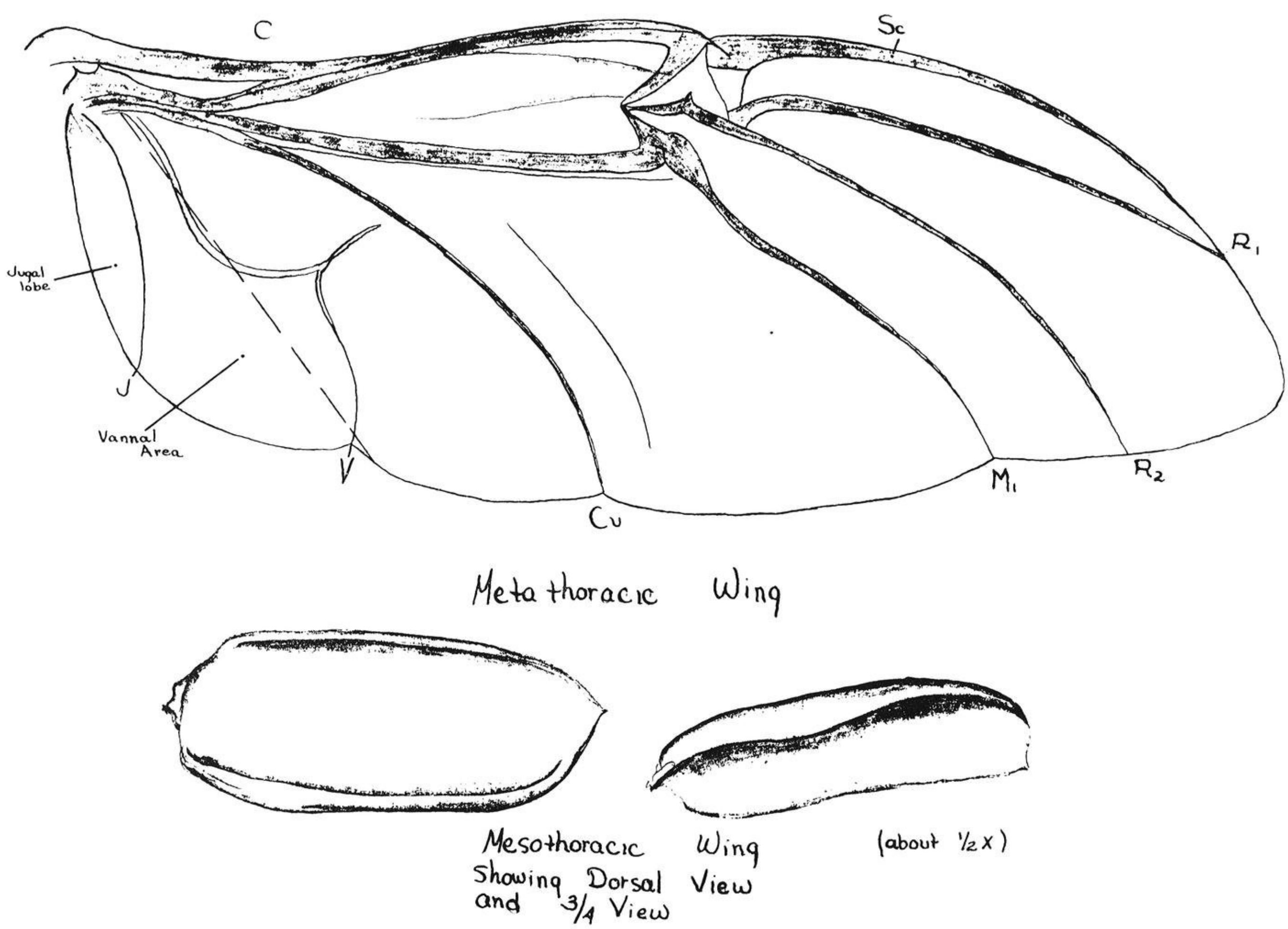
This insect has four wings. The anterior pair or mesothoracic wings are hardened or scleritised and are called elytra. They have no definite function in flight but merely serve to protect the delicate membranous metathoracic wings during rest. While the insect is at rest, these wings cover most of the insect from the mesothorax down over the abdomen, leaving just a portion of the last abdominal metamere exposed from the dorsal view. See Plate 1. The posterior pair of wings on the metathorax are membranous and serve in the flying mechanism of the insect.

Wing Veination

Because the wings have gone through great evolutionary modifications, the wing-veination of both pairs are difficult to study. In the elytra, because in the loss of flight and being scleritised, the veins are considerably reduced. In the metathoracic wings, because of an intricate transverse folding system, the normal wing veination has undergone great modification: See Plates 8 and 9. It was found in literature that through ontogenetic methods, one can homologise and name the veins by looking at pupal wings.

It was found, for example, in the coccinellid beetle, *Hippodamia 13-punctata,* that previous to their emergence from the larval wing-pockets, there was no difference between fore and hind wings. But after this, the fore wings thickened with hypodermal cells on the

Plate 9



dorsal side, while the hind wings grew thinner and expanded in area. And the tracheation in both of these wings in the first stage were very closely matched.

It was also found that a reduction in the anal area of the elytra resulted mainly because in the adult the two elytra lie in a straight line down the dorsum of the back, and the back does not admit of an expanded anal area. Plate 10 shows an example of this type of tracheation during the pupal stage (redrawn from *The Wings of Insects*, by J. H. Comstock).

Insect Flight

To fly, the insect must be able to create a difference in the density, or pressure, of the air on opposite sides of itself. Motion takes place toward the region of lowered pressure. So when the insect takes flight, his beating wings set up air currents and, hence, produces different air pressures. The convergence of the air currents behind the insect sets up air with greater pressure in that area. Then the lower pressure above counteracts the weight of the insect, and it moves forward into a low-pressure area by the push from behind by the higher pressure.

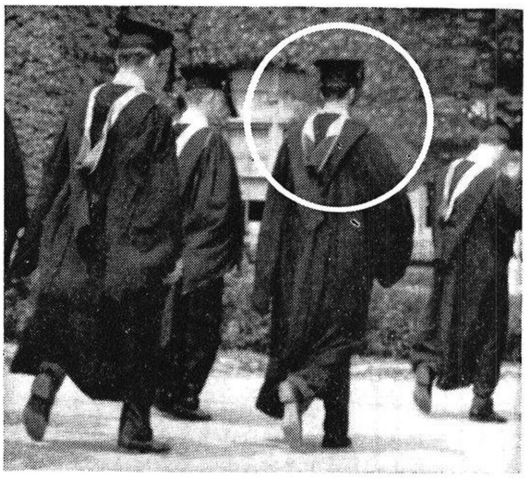
The beetle's wings are held at a quite horizontal position and beat at a very low pace, hence, his flight is very slow. His body is very heavy, so with his slow wing movements, the flight is a very sloppy one.

Wing Steering Mechanism

Studies made by Stellwaag (1916) found that in the steering mechanism of the insect, the body and legs show very little movements and, hence, do not aid in steering. The wings, then, are the sole factor in flight direction. He found that insects turn by a differential action of the wings while they are vibrating in flight. In other words, one wing merely beats at a faster rate than the other, causing a turn. The direct muscles of the basalar and subalar are solely concerned in this, since the indirect longitudinal and tergosternal muscles cannot control individual wings because they are not attached directly to them. It was also found as mentioned earlier that if the axillary region were shifted, the axillary muscle was another contributing factor to a minor degree in shifting direction.

Plate 7 shows relative movements of the wing of a generalized insect which also pertains to the

(Continued on page 32)



John LaCost wanted a part in scientific progress

He has it at Western Electric

John LaCost received his B.S.E.E. from the University of Illinois in 1962. One of the factors which influenced him to join Western Electric was the quick manner in which new engineers become operational.

During the short time John has been with us, he has worked in several areas which are vital to the nation's communications complex. And with his future development in mind, John attended one of our Graduate Engineer Training Centers where he studied the front-line Electronic Switching System. He is currently working as a systems equipment engineer on such projects as crossbar switching and line link pulsing.

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Thin Shell Membrane Structures

By Dallas Forester CE-4

IF YOU have ever tried to break an egg by exerting a compressive force along its longitudinal axis, you know that it is very difficult to crush it, despite the fact that the shell is very thin and weak in bending.

Since the time of the Roman empire men have tried to duplicate nature's feat by making a thin shell that could cover a very large span while employing a minimum amount of intermediate support. It was not until about 30 years ago, at which time a Frenchman built a locomotive shed outside of Paris which employed a large span thin shell for a roof, that thin shell structures have become an accepted method of construction.

This article presents a survey of thin shell structure practices today, and their impact on the construction industry.

BASIC DESCRIPTION OF SHELLS

General Definition

A thin shell is a structure that is used in roof construction employing the concept that all bending stresses are nil while tension and compression are dominant. Combining this with the fact that thin shell membranes transfer their weight in the form of thrust to their end supports, thin shells are able to span long distances without having to resort to the frequent use of intermediate floor columns for support, as is the case with ordinary beams which exert dead weight perpendicular to themselves. Because the shell membrane is so thin, it requires less material than conventional roofs and is therefore more economical in this respect. The designs which are possible in this type of roof lend an aesthetic value to the building also.

Types and Purposes of Shells

One of the more common forms of shells is the one of double curvature, known more commonly as the hyperbolic paraboloid. This shell can be used in many situations and is well suited for the construction of such buildings as factories and office buildings which require large span roofs.

Cylindrical forms are the most common type of shell and generally are used where spans are not so demanding. Barrel vaults are a common type of cylindrical shell and lend themselves very well in the making of a large composite roof of several cylinders. This method has been employed quite frequently for schools and office buildings.

Another type of thin shell is the shell of revolution or dome. The dome is exceptionally well suited for spanning such buildings as gymnasiums which demand a high roof, but a minimum number of intermediate spaced columns.

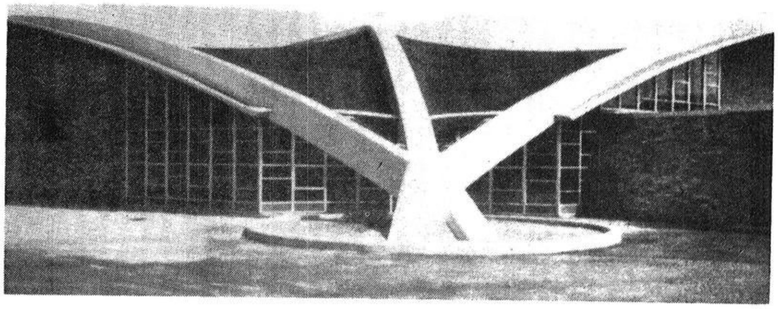
A last form of thin shell is the folded-plate which is well adapted to a cantilever type roof such as can be used over a grandstand or loading dock. This type is somewhat different in shape as compared to the ordinary curved shell, but still employs thin membranes.

THE DESIGN OF SHELLS

The actual engineering design of a thin shell is perhaps the most difficult stage since ordinary design practices very seldom apply. A very careful analysis of the proposed structure must be made in order to ensure its safety; and this is why it is so important for the civil engineer and architect to work closely together when designing one of these structures.

Theoretical Analysis of Strength and Stiffness

As mentioned above, thin shell membranes cannot be treated like ordinary beams which have distinctly separable phases of design. Primary stresses of compression or bending moment and shear across a beam can be solved for separately since as a rule only one combination predominates. If an analysis of the stiffness of the joints is needed, the bending stresses which result can be treated as secondary stresses.



Above is an example of a hyperbolic paraboloid.

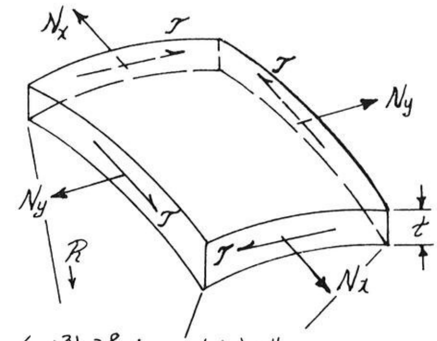
Sections of a sphere and two cylinders form the roof pictured above.

In thin shell membranes however, these primary and secondary considerations are no longer separable due to the shape of the shell. To get around this problem, approximate methods of analysis are used. Although these methods do not wholly resemble those used in the conventional design of beams, the linear theory of elasticity is still employed. Plastic theories of analysis have been used in some cases, but are still not sufficiently developed to always ensure a safe, reliable solution.

At present there are numerous approximate methods of analysis that have been successfully used in designing thin shells. There are practically no empirical formulas as for conventional structures however, due to the highly complex nature of thin shells which discourages the construction of an accurate scale model of a proposed shell in order to check on theoretical stress calculations.

For this reason thin shells must always be overdesigned since very little actual working stress knowledge has so far been attained.

Of all of the approximate methods of analysis presently available to the engineer, the Schorer method of approximation is the simplest to use. This equation has combined the thickness (t), dimensions (x, y), radius of curvature (R) and displacement (w) into one compact, linear differential equation of the eighth order in which w is the sole dependent variable and can be directly calculated. Even though this equation is greatly simplified, it is still difficult to solve and there has been an increasing trend towards the programing of these solutions on high speed digital computers. There still remains much to be done along this line however.



$$\left(\frac{t^3}{12}\right)\frac{\partial^8 w}{\partial y^8} + \left(\frac{t}{R^2}\right)\frac{\partial^4 w}{\partial x^4} = 0$$

Fig. 1.
Formula for Schorer method of approximation.

Stress Analysis of Shells

Just as in conventional stress analysis of beams, etc., thin shells can be classified as either statically determinate or statically indeterminate structures. Generally they are of the latter type however.

Statically Determinate Shells. There two basic problems which must be solved in a statically determinate shell. These are solutions of the membrane stresses themselves and of the edge beams which support the shells. Once the membrane stresses have been determined, statical equilibrium can be arranged at the edges of the shell and the desired displacements to ensure equilibrium can be found.

Membrane stresses can most conveniently be solved for by using a version of the Hardy Cross method of solution. What this method does is to solve for four sets of shears (one set for each component displacement) acting on the membrane, and the same number acting on the edge beam to cause unit displacements in each of the component directions. Upon adding these various components, we can determine which forces must be applied to effect unit displacement of the composite shell and beam. We can then determine the displacements which result from the application of the unknown edge forces and arrange for equilibrium.

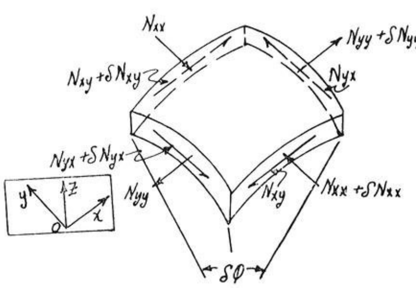
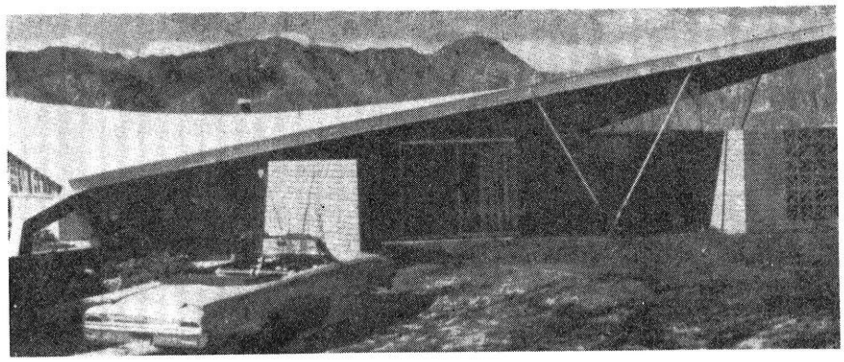


Fig. 2.

Hardy cross method of solution.

Since the solution of the block of 16 numbers required for unit interaction of the shell and beam is a tedious process, matrices can be conveniently applied which provide a self-checking solution to the problem. Also, matrices have been shown capable of cutting down the computation time required from 24 hours to 16 hours.

Statically Indeterminate Shells. The solution on indeterminate shells is somewhat analogous to the solution of determinate shells as discussed above. The solution of the membrane stresses is identical,



House roof consists of ribbed steel-deck membrane, stiffened with channel edge-rib.

but a different method of analysis is needed to solve for the edge beam reactions since there are too many unknowns to solve for with the conventional Hardy Cross method of solution.

The flexibile coefficient method is probably the most adaptable to the solution of a statically indeterminate shell structure. After enough elastic equations (e.g. the Schorer equation) have been developed, the calculation of the integration constants remains the only problem. Basically what the flexible coefficient method entails is the removal of edge beam reactions and the building up of a number of deflection equations equal to the number of unknowns at each section along the edge beam. These equations are then solved to ensure equilibrium at each section and eventually of the entire shell. Ordinarily the deflection at any reaction must be zero and this simplifies the solutions somewhat.

Loadings Encountered. Just as in any engineering structure, the reactions must be designed so that the anticipated loadings can be supported. Snow, wind and dead loads are usually the main considerations in any roof structure. However, in the design of a thin shell it has been shown that due to the curvature of the shell membranes, wind load stresses are almost negligible. This is a distinct advantage over other room designs and one which makes them especially well adapted to buildings where large internal pressures are built up such as in airplane factories, etc.

CONSTRUCTION OF SHELLS

Just as it is very necessary for the architect and engineer to work closely together in the conception and design of the shell, it is equally important to have complete argreement between the civil engineer and contractor in the actual construction of the structure. Materials of construction, reinforcement and formwork are some of the basic considerations to be agreed upon.

Materials Used

At present the most commonly used material of construction is concrete which can be poured into almost any shape, thick or thin, dependent only upon the number of reinforcing bars used. However, concrete has the one disadvantage of being a very heavy material, weighing around 150#/ft^3, which usually means the use of extra strong supporting columns. For this reason such materials as plywood, which has been used in structures varying from folded plates to barrel vaults; plain steel deck membranes, to make folded plates; light-gage steel deck, which has been used for hyperbolic-paraboloid roofs and ceramic shells, which can span up to 300 feet are becoming increasingly competitive as construction materials. No doubt we will see more of their use in the future.

Reinforcing of Membranes

There are two basic methods of pre-stressing concrete shells, pretensioning and post-tensioning, both of which are used in conventional beam design as well.

Pre-tensioning is the name given to ordinary reinforcing procedures where pre-arranged steel wires are cast right into the concrete as it

(Continued on page 32)

Assignment: design a car for tomorrow... that could be built today!

Result: Allegro, an experiment in advanced automotive ideas that are practical for the near future

Allegro means "brisk and lively," which certainly describes Ford Motor Company's new dream car, a handsome fastback coupe. More than that, Allegro has unique functional features that could be adapted for future production cars. (This has already occurred in the case of retractable seat belts!)

A major innovation is a cantilever-arm steering wheel with an electronic "memory." The steering wheel is mounted on an arm that extends from a center-mounted column. The wheel swings upward for easy exit, returns automatically to its former position at the touch of a button. Power adjustment enables it to be moved three inches fore and aft and five inches vertically. This, plus power-adjustable foot pedals, permits use of a fixed seat design for low overall height.

Basically a two-seater in present form, Allegro has rear floor space that could be converted to carry two additional passengers. The car could be powered by either a V-4 made by Ford of Germany or by the domestic 144- or 170-cubic-inch Sixes.

Allegro is one of a series of Ford-built dream cars which will be shown at the New York World's Fair to test consumer reaction to styling and mechanical innovations. This will help determine which of their forward-looking features are destined for the American Road—as further examples of Ford Motor Company's leadership in styling and engineering.

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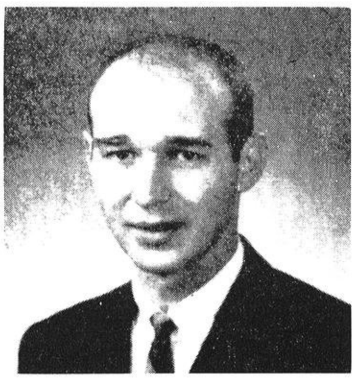
Ultrasonics and Its Industrial Applications

By Thomas L. Hopkins



Tom is a senior in mechanical engineering at the University of Wisconsin and is interested in process engineering. Some of his activities include the student chapters of the ASME and the SAE.

ULTRASONIC SOUND

THE term "ultrasonics" is used in acoustics to denote the range of frequencies which are beyond the limits of hearing of the human ear. This range of frequencies goes from 20,000 cycles per second (cps), and upward (frequencies as low as 10,000 cps are called ultrasonic, but loosely so). The upper limits of the frequencies of ultrasonic oscillations are bounded by the most recently obtained frequencies of 10^8 to 10^9 cps, and are consequently, adjacent to the hypersonic range, which extends up to the frequencies of the order of 10^{13} cps.

ULTRASONIC WAVES

Ultrasonic waves can be propagated in any elastic body: liquids, solids, and gases. The form of the wave, generally longitudinal or transverse, depends on the elastic properties of the medium. In gases and liquids, sound waves may be of only the longitudinal type. In a solid body both longitudinal and transverse waves can be propagated.

In the propagation of a longitudinal wave in a medium there arise successive regions of compression and expansion. Thus, for example, for a standing wave, at points having maximum amplitude, i.e., at antinodes, we will have a region of compression and, correspondingly, at the nodes there will be rarefaction. For a traveling wave the nodes and antinodes alternate at any point in space. The fact that sound waves in liquids and gases are longitudinal is due to the existence of only one elastic modulus for these media. In the deformation of close compression the elastic forces behave like normal pressures, and the motions elicited by them proceed in a direction perpendicular to the front of the traveling sound wave, i.e., in the direction of propagation. In solids, which have a form elasticity, along with the normal stresses of volume deformations, there also arise tangential shear stresses. The deformations associated with them are propagated in the form of transverse waves, where the oscillatory motions of the particle in the medium proceed in a direction perpendicular to the direction of wave propagation. Thus, in a solid body, both longitudinal and transverse waves can be propagated. In a purely transverse wave, compression and rarefaction of the medium do not occur.

THE PROPAGATION OF ULTRASONICS

There are three basic means of propagating ultrasonic sound waves. They are piezoelectric, magnetostriction, and mechanical. They are all different in nature and their frequency limits vary.

PIEZOELECTRIC

The brothers Curie discovered in the year 1880 that many crystals, which lack a center of symmetry and are subject to pressure or tension, develop electric charges on definite crystal surfaces. This phenomenon was named the Piezoelectric effect (Piezo taken from the Greek word Piézen which means to press or squeeze). The reverse of this effect may take place, (e.g., an electric charge may be applied to the crystal causing a change in its physical dimensions). Upon such excitation, a properly cut crystal, when employed as a transducer, will produce an ultrasonic wave with a frequency corresponding to that of the applied voltage.

The crystal itself may be made of common table salt (NaCl) but from every point of view—durability, economy, ease of manufacture, and simplicity—the quartz crystal (SiO_2) is one of the most desirable of all types that may be chosen for ultrasonic work. As was mentioned, a crystal which lacks symmetry about a polar axis must be used. A polar axis or direction in crystallography is defined as an imagined direction in the crystal, the two ends of which are not equivalent—that is to say, cannot be interchanged. The quartz crystal as shown shows the polar axis X_1, X_2, X_3, and the symmetrical axis Z (the Z axis is not a polar axis). If the crystal is rotated 180° about any of the X axes an identical face will not appear.

The greatest physical distortion takes place along these polar axes when an electrical voltage is applied. It is therefore logical to cut from the quartz crystal a plate or rod which has its axes parallel and normal to one of these polar axes.

To produce the greatest amount of distortion in the crystal it is necessary to vibrate the crystal at one of its normal frequencies which then will produce a resonant amplification.

The crystal after being cut from the mother crystal may be shaped to form convergent, divergent, or straight sound waves, depending upon their ultimate uses.

The frequencies produced by the quartz crystal depend upon how the crystal is cut and the actual dimensions of the crystal. It is also dependent upon the temperature at which the crystal is operating.

The piezoelectric effect is used to produce ultrasonic frequencies from 10 kcps to well within the megacycle range.

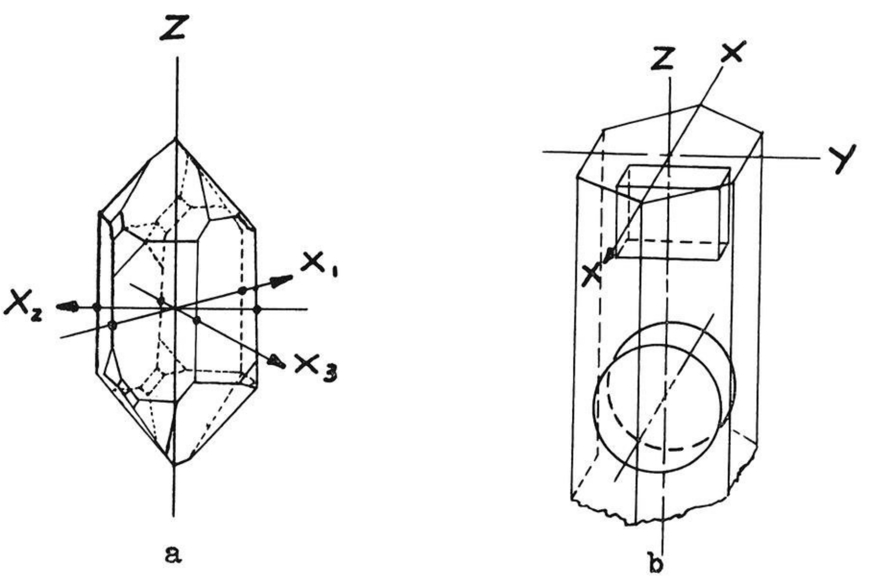
MAGNETOSTRICTION

If a rod or tube of ferromagnetic material is brought into a magnetic field parallel to its length, a change in the length of the rod or tube is produced. This is the basis of the phenomenon known as magnetostriction, or as the Joule effect, after its discoverer.

The effect of magnetostriction is generally produced by the transformation of an alternating electric current. This may be most easily explained by recalling a simple physics experiment. If a bar magnet is passed through a wire coil, an electric current will be produced in that coil. By extrapolation, then, let a bar magnet be 'moved' in a coil by applying tensil or compressive load to the bar magnet. Upon compression or elongation of the bar magnet, no matter how small, a current will be produced in the coil. If the bar is vibrated by this means, a voltage will be produced in the coil with an amplitude proportional to the elongation or compression, and with a frequency equal to that of the vibration. A reversal of this effect is also possible. If an electric current is applied to a coil wrapped about a bar magnet, an elongation or shortening of the bar magnet will take place. The changes of length so produced are comparatively small. The relative changes of length being of the order of one part in a million, or dL/L is of the order of 10^{-4} to 10^{-6}, where L is the length of the magnetic rod. When this effect is applied to a rod and employed as a transducer, ultrasonic sound waves can be effectively produced up to 60 kcps.

The magnetostrictive effect is observed both in pure ferromagnetic-nickel, cobalt, iron, and in alloys of nickel with ferromagnetic and non-ferromagnetic materials. Magnetostrictive properties are most sharply pronounced in an alloy of iron and cobalt (Permendure) and in pure nickel and its alloys, e.g., with iron (Invar, Permalloys), where an elongation of approximately 30 parts in a million will be produced. To amplify this effect over a large square inch area it is desirable to go to laminated assemblies.

To obtain the maximum elongation the frequency input to the rod must correspond to the natural frequency of the material which will then cause a resonant amplification. The temperature of the metal, for maximum elongation, must also be maintained at reasonable temperatures, (e.g., below 100° C). This is generally accomplished by water cooling.



(a) Quartz crystal. (b) cutting of quartz plates and rods from a crystal.

MECHANICAL

Galton Whistle

With the so called Galton Whistle, it is possible to obtain ultrasonic oscillations with frequencies up to 100 kcps. The operating principles of the whistle is the following. A stream of air, directed through a narrow annular slit, impinges on the sharp edges of a cylindrical tube (resonator) and gives rise to acoustic oscillations with a frequency equal to the natural frequency of the resonator. By varying the length of the resonator it is possible in such a way to change the frequency of the generated oscillations.

Gas-Jet Generator

In the gas-jet generator the source of ultrasonic oscillations is a periodically variable pressure along the jet of out flowing gas. With a hydrogen blast in gas-jet generators, oscillations can be obtained with frequencies up to 500 kcps, and in the 10–20 kcps range, sound is obtained with a power as high as 150 watts.

SIREN. A siren basically consists of a source of air such as a compressor, a ported stator, and a rotor which interrupts the air through the parts. A rotor driven motor of ½ to 1 hp. at 133 rps will drive a unit producing 300 to 1,200 watts at from 3 to 30 kcps. An air supply of about 60 ft^3/min is required and is led to the ports by baffles giving equal distribution. At the high frequency end the ports radiate well, but at the low-frequency a horn may be added.

With an air pressure of two atmospheres, the acoustic power generated by the siren attains 2,000 watts. To visualize such power, a wad of cotton, when placed in the acoustic field of such a siren, will burn up in six seconds, while a steel rod will become red hot after one minute.

With these four basic means of propagating ultrasonic sound waves in mind, let us now turn to see how they can be applied to industrial uses.

ULTRASONIC APPLICATIONS

Cleaning

Ultrasonic cleaning is thought to be due to a combination of cavitation and acceleration of the cleaning fluid—generally a water-detergent solution, trichlorethylene, or Stoddard solvents.

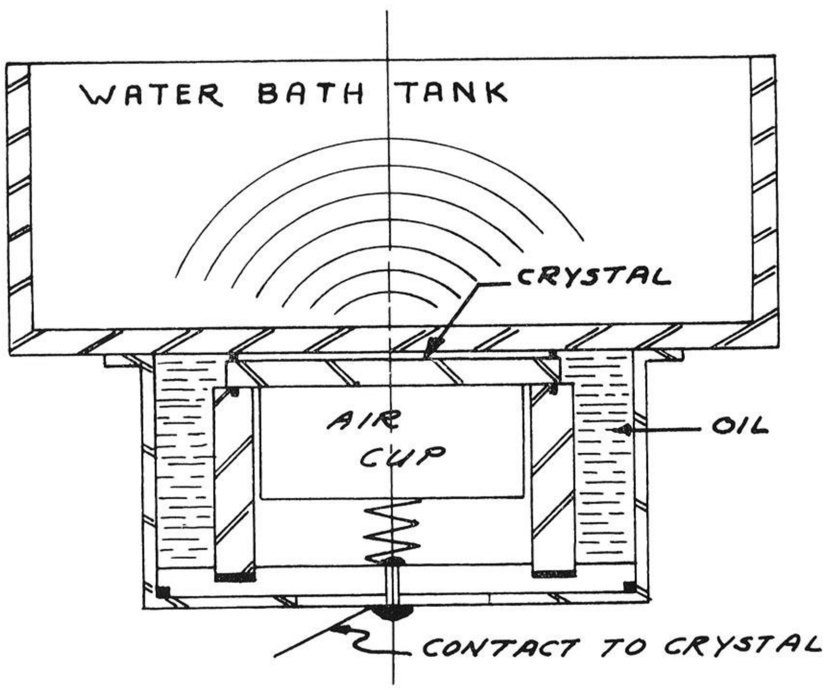
An ultrasonic cleaning unit is composed of three components. There is a generator or motor-altenator, transducer—in this case it is a piezoelectric crystal—and a cleaning tank. The generator produces A-C electrical energy. The transducer, coupled to the generator by a co-axial conductor, converts the electrical impulses into high frequency sound waves which, in most cases, are above human hearing and extend into the megacycle range.

Cavitation takes place in the liquid when high frequency sound waves are transmitted through it causing an alternating compression and expansion of the medium. On the expansion half of the cycle, which corresponds to a slight negative pressure alternating about the ambient conditions, microscopic bubbles are formed. Since most liquids are inelastic and have no tensile strength, negative pressures cannot be sustained, and when the alternating pressure goes into the compression half of its cycle, it causes an implosion of these microscopic bubbles which release an instantaneous burst of energy in the form of heat which may reach temperatures of several thousand degrees Fahrenheit, accompanied by pressures of even greater magnitude. This instantaneous release of energy produces a powerful scrubbing action which pulls soil particles from the part being cleaned.

The particle displacement, caused by the sound waves for a given amount of power, is inversely proportional to frequency and is much larger at low frequencies than at high frequencies because the wave length of sound in any medium, such as a liquid, is inversely proportional to the frequency.

The cleanness (cleanness is preferred terminology in ultrasonic cleaning work) of close tolerance parts in the past few years has been of growing concern, but a method of handling delicate parts which require a very high degree of cleanness produced the demand for ultrasonics, which up to this period (1957 and before) had been more or less a laboratory toy.

Ultrasonic cleaning has ranged in use from cleaning miniature bearings to the decontamination of radioactive exposed materials, and it appears as if the uses of ultrasonics as a cleaning aid are almost unlimited.



An ultrasonic cleaning tank.

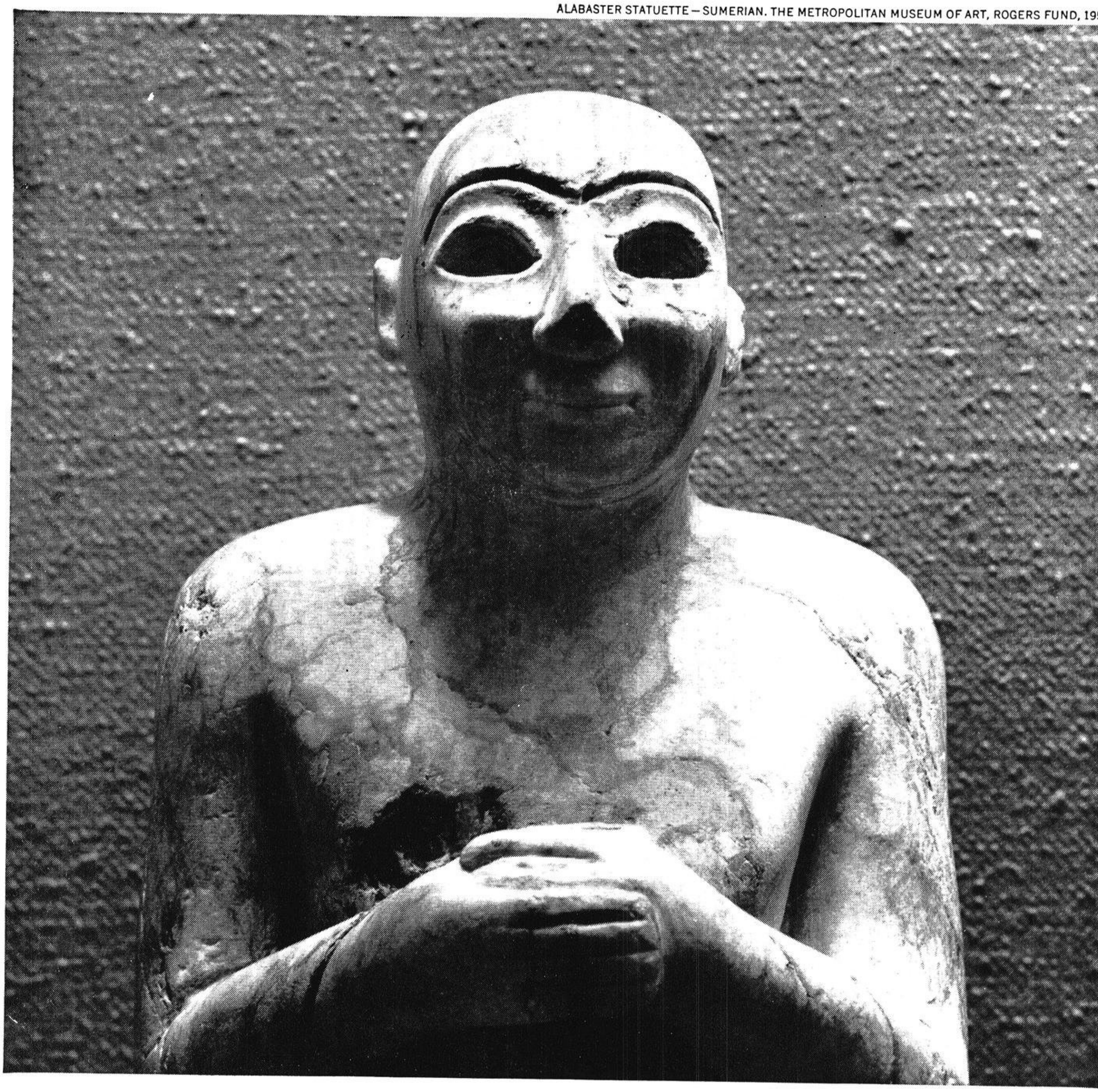
METAL DRILLING

The primary importance of ultrasonic metal drilling is its ability to cut such materials as tungsten carbide, hardened tool steels, and ceramics quickly and easily. It involves very low stresses and no local heating. As a result there is no thermal cracking, pitting, or burnt solor left on the work surfaces. Ultrasonic drilling also facilitates a freedom in design when employing these materials. Soft materials like plastic and lead, on the other hand, are not suited for machining by this process because they tend to absorb the abrasive particles rather than chip under their impact.

Metal cutting with ultrasonics is accomplished by vibrating a soft tool at high frequencies and low amplitudes against a work-piece while a mixture of finely di-

(Continued on page 38)

ALABASTER STATUETTE—SUMERIAN. THE METROPOLITAN MUSEUM OF ART, ROGERS FUND, 1950.



He was a great scientist in his day

This Sumerian was minding our business five thousand years ago.

Like Olin, he specialized in chemicals and metals. He smelted copper and tin to make bronze. He made an iron axle, put it between two wheels, and off he went.

Men have always been trying to find the answers to important problems. Today, Olin is at it, harder than ever.

Our pioneering research in liquid chlorine helped eradicate typhoid and other water-borne diseases.

Our anti-tubercular drug, NYDRAZID® is a major reason TB deaths decreased 60% in the last eight years.

Olin's ammonium phosphate fertilizer (Ammo-Phos®) makes it possible for farmers to grow more food than ever before.

And to prevent the tremendous waste in food spoilage, we're working on an antibiotic-coated plastic wrapping.

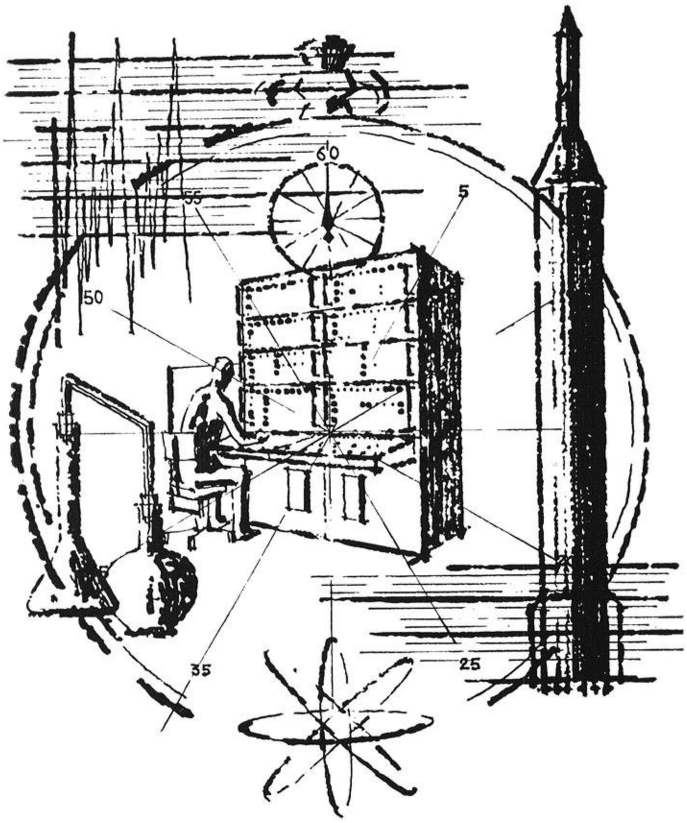
Olin

"An Equal Opportunity Employer"

To take a big sting out of life, Olin is developing a high speed cartridge that enables medicine to be injected without the use of hypodermics.

But none of these advances could have been made without our scientists.

Every division of Olin seeks the creative, scientific mind for the answers to the research problems of our day. If this is the kind of work that interests you, call Olin or write to M. H. Jacoby, College Relations Officer, Olin Mathieson Chemical Corporation, 460 Park Avenue, New York 22, N.Y.



SCIENCE HIGHLIGHTS

By Robert Rosenberg, ME'65

WORLD'S MOST POWERFUL LIGHT BEAM

The world's most powerful continuous beam of light, and also the hottest, has recently been developed. In two or three seconds it can burn through a piece of steel as thick as an automobile fender.

Unusual features of the new light source are:

1) Its radiant energy comes from a high-pressure plasma jet, hotter by far than the surface of the sun.

2) The jet is sealed inside a stainless steel vessel designed to operate at pressures up to 600 pounds per square inch—40 times the pressure of the atmosphere at sea level.

3) One-half of the pressure vessel is a deep elliptically shaped mirror that collects about three-fourths of the arc's radiation and beams it out through a quartz lens-window set into the other half. Conventional light sources, such as those used in automobile headlights and searchlights, use a parabolic-type mirror. Such a system seldom collects more than one-half of the generated light.

The new radiation source is designed for an input power of 50 kilowatts. At this input power, the beam will concentrate about 15 kilowatts of radiant energy on a spot half an inch in diameter.

During operation, an inert gas flows continuously through the device, entering near the window and leaving as a plasma jet through a hole in the anode. The gas flow stabilizes the arc and also flushes out vapors to prevent mirror contamination. Both cathode and anode are water cooled. The cathode is made of tungsten and the anode either of copper or tungsten. Both electrodes can be adjusted for starting and for regulating the length and position of the arc.

The output of the radiation source is intense in the visible light spectrum and very rich in the ultraviolet region. Temperature and emissivity of the plasma arc are controlled by varying the arc power and the chamber pressure. Radiation wave length decreases as arc temperature increases, and spectral line widths increase with chamber pressure. Any inert gas or mixture of inert gases can be used, and the spectral distributions radiated are characteristic of the gas used.

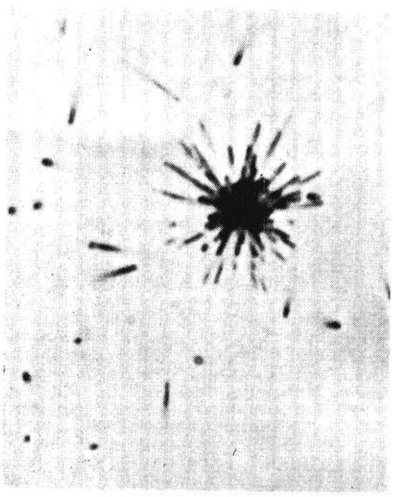
Possible uses of the new light source include simulation of re-entry heating, high-intensity searchlights, laser pumping, arc imaging furnaces for melting metals and ceramics, solar simulation, catalyzing, chemical reactions, welding, image projection, airport illumination, and advanced military applications.

NEW DATING TECHNIQUE

The tiny atom, like the lumbering dinosaur, has left permanent "fossil" tracks in the earth's rocks. Overlooked by scientists until now, the newly-discovered atomic tracks found by General Electric scientists hold a key to the age of the minerals in which they are preserved.

The atomic tracks were discovered in a piece of mica, a mineral found in rocks throughout the world. Minerals, including mica, contain a trace of uranium, a radioactive element. The atoms of uranium are unstable and decay at a known rate into atoms of elements that are not radioactive. Ever since the minerals solidified from molten material, this clock has been ticking away. Some of the uranium atoms decay by undergoing fission, splitting spontaneously into two fragments of approximately equal size. As the fission fragments move away, they leave a trail. This damaged region, about 0.0005 inch long by a few atoms in diameter, constitutes a permanent "fossil" record of each tick of the atomic clock.

At first the tracks could only be seen with an electron microscope. However, it was discovered that by dipping the sample in hydrofluoric acid the tracks could be enlarged enough to be seen even through a low-power optical microscope.



New technique for dating geological specimens is based on discovery of "fossil" particle tracks produced in minerals by uranium atoms which underwent natural fission. This extreme close-up—magnified 5,000 times—shows burst of "fossil" tracks radiating from speck of uranium in sample of mica, a common mineral. Individual tracks in background were produced by fission fragments from single uranium atoms.

NEW ELECTRONIC EYE FOR RESEARCH

Scientists are getting a better look at the atomic makeup of matter with the help of a new electron diffraction camera. Some two to five times more powerful than the usual electron diffraction camera, the new instrument will provide more detailed pictures and brighter images, and will make possible the study of thinner surface films and thicker transmission specimens.

An extra-high voltage—250,000 volts produced with an electrostatic generator—is used to accelerate electrons released from a tungsten filament to 90 percent of the speed of light. (The wave length of these accelerated electrons is about 200,000 times shorter than that of light.)

These high-speed electrons are focused by magnetic and electric lenses, and beamed onto a material specimen under study. The electrons are diffracted as they pass through the material's atomic structure, and the atomic arrangement of the material is determined from the patterns produced on a fluorescent screen or photographic film. Structural materials for space vehicles and nuclear reactors will be the first specimens to go under the eye of this new test instrument.

PRODUCERS PREDICT NEW APPLICATIONS FOR SEAMLESS TUBING

New applications for seamless specialty tubing, ranging from the underwater search for oil to space exploration, were predicted at a seminar staged here recently by the American Iron and Steel Institute.

The industry is meeting competition from bar stock, forgings and a variety of non-ferrous products by improved technology and active exploration of new, previously, untapped application areas.

Competition to the 75-year-old product from welded tubing is limited to clearly defined areas. Both seamless and welded tubes have special areas of interest. There is relatively little overlap. The prime new markets for seamless tubing are those where mechanical applications are currently filled by bar stock, forgings and non-ferrous products.

Further Growth Predicted

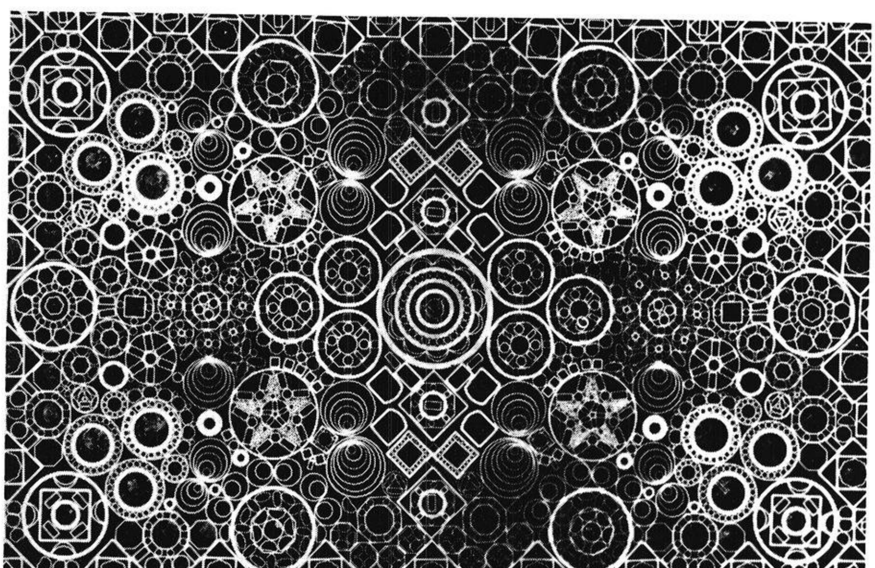
As evidence of the industry's present strong position, 654,000 tons of seamless specialty tubing were shipped last year—almost 50 per cent more than the tonnage of welded tubing reported.

Today tolerances are approximately half what they were 20 years ago and that tubing lengths have been increased substantially in the same period.

Sizes and other dimensional criteria have also kept pace with the industry's progress. Seamless tubing is now available in OD sizes ranging from 0.005 to 14 in. and with wall thickness from 0.0015 to 3 in. Round, square, rectangular and special shape tubing also generally available today.

The fact that seamless tubing can be internally or externally splined, tapered, expanded, cupped, swaged, flanged, coiled and subjected to any other fabricating technique further extends the material's versatility.

(Continued on page 32)



As this "lacework in steel" beautifully illustrates, seamless steel mechanical tubing comes in a tremendous variety of sizes and shapes, and it is used in an amazing variety of jobs from hypodermic needles to bulldozer parts. Seamless means strength, dependability, and versatility.

This versatility, which assures a virtual custom-tailoring in seamless tubing, plus freedom from seams, make seamless the most desirable structural element material with the highest strength-to-weight ratio of any tubular metal product. The same qualities offer the utmost in critical reliability in applications involving high temperatures and pressure where failproof systems are required.

Seamless tubing has often proved to be the most economical material from which to make cylindrical mechanical parts. While seamless costs more per pound than bar stock or forgings, its use eliminates most machining and fabricating and substantially reduces overall per-piece costs of the finished product.

These advantages broaden horizons for process and product engineers in many fields. Seamless tubing is a tailored product without limitations in scope and can be produced in any materials, grades, conditions, shapes or properties needed by any industry.

Other Technical Advances

Other major technical advances, include the development of practical methods for producing seamless tubing from almost every analysis, including stainless and high-alloy steels and the newer, more exotic materials. Moreover, heat-treating methods have been vastly improved in recent years. Specialty seamless tubing is now available in "a virtually unlimited variety of heat-treat conditions." Surface finishes to meet a variety of applications are also possible today through many newly developed fabricating operations.

Flight System

(Continued from page 20)

June beetle. (redrawn from *Principles of Insect Morphology* by Snodgrass)

Since I did not use any live specimens of *Phyllophaga rugosa*, I cannot tell you exactly what lies behind the flexion of the wings, but the following is a brief observation from Snodgrass as to the process.

Flexion of Wings

Flexion begins with the relaxing of the extension muscles which allow each wing to turn a little posteriorly. This causes a buckling or convex fold at the base of the mediocubital field along the line of the plica basalis which is between the two medial plates. At the same time, the third axillary sclerite revolves upward on its basal articulations. The axillary or flexor muscle then upon contraction continues this revolution of the sclerite, turning it dorsally and mesolly until it is completely inverted and reversed in position. This movement also brings with it the vannal area which is lifted and carried horizontally against the back while indirectly turning the remigial region posteriorly on the articulation of the subcostal and radial veins with the first and second axillaries producing a convex fold along the plica basalis at the base of the mediocubital field.

As the posterior edge of the flexing wing comes against the side of the insect, the jugal lobe is deflected and folded beneath the vannus.

Extension of Wings

In the extension of the wings, the flexion process is reversed. The flexor muscles must relax and either the contraction of the basalar muscles at the costa area of the wings pulls the wing out or the produced buckling of the axillaries can be flattened out in a horizontal plane by the contraction of the subalar muscles at the second axillary causing the whole axillary area to spread out the wing in an extended position.

It might be added that with the modification of the costa and subcosta veins there forms an unordinary joint midway within the wing causing the wing to fold in an even more complex fashion during the flexing process. Modification in the radial and medial veins has also compensated for this.

This completes the flight system of *Phyllophaga rugosa*. A lot yet remains to be answered, but this gives an insight as to just how complex this system is.

Thin Shell Structures

(Continued from page 24)

hardens. This method is well adapted for the shell, edge beams and stiffening beams. It requires very heavy abutments since the ends of the wires are fastened to these before being put into tension.

Post-tensioning can be used to bind these components together after they have once hardened. Generally the wires used in the post-tensioning process are either protected from the concrete by casting holes in the members being stressed, or by providing some kind of continuous sheath which also separates the wires from the concrete. In any case, heavy jacks are employed to apply the tension force needed, after which the wires are crimped into a permanent stress. Whether used singly or in combination, both pre-tensioning and post-tensioning greatly increase the supporting strength of the final structure.

Formwork Used

Just as in any concrete structure, formwork must also be used in thin shell construction to provide a place to pour the concrete. Shuttering is the term which is used for this process. Many contractors and engineers alike feel that the correct installation of shuttering is the most important single aspect of thin shell construction and often the most expensive.

There are naturally many other situations also where formwork is needed, such as when casting beams or deck membranes, all of which require different procedures.

Wood, steel and even fiberglass can be used in making the formwork. On large jobs these forms can be moved from one place to another after the initially poured concrete is hard, thereby saving in formwork costs.

FUTURE OF THIN SHELL STRUCTURES

Up until recently there was not very much thin shell construction in the United States; instead, Europe was the most active in this field. However, thin shells have been becoming more prominent here.

(Continued on page 37)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Miss December

MARTHA FOLLSTAD

Due to the popular demand of the boys from Kronshage Hall, Martha was chosen as our girl of the Month for December.

Martha, our five foot two blonde from Ross House, Cole Hall, is a native of Rhinelander, Wisconsin's skiing center.

Pledging Pi Beta Phi, majoring in English, and enjoying winter sports all find an interest in Martha.


MATHIS

The Night Before Christmas (Vacation)

DAVE BEAR

'Twas the night before vacation
And all through the nation,
Not a creature was stirring 'cept me.

My roommates were nestled all snug in their beds
While visions of frolic danced through their heads.
Dressed in my nightshirt, I turned on the lamp
To see how the box would slide down the ramp.

For hours I struggled with equations of statics
Which could not be solved by simple mathematics.
When somewhere above me there arose such a clatter
I sprang from my chair to see what was the matter.

I threw back the curtains and opened the window.
But couldn't see a thing.
The moon shimmered off on the new-fallen snow,
Giving eerie shadows to objects below.

I returned to my chair start summing up forces.
And cursed the department for requiring such courses.
And what to my sleep-drowsed eyes should appear,
But a fat little man that smelled like reindeer.

He was dressed all in red from his head to his toes,
And stood two inches high from his feet to his nose.
Needless to say, I was startled a bit,
Though I knew long ago, it was past time to quit.

He said not a word, but went straight to my work,
I could tell no one, lest they think me berserk.
He was dwarfed by my pencil, but he used it with ease,
And sailed through my problem like it was a breeze.

Then he turned and he laughed like a jolly old elf,
And I nodded and smiled in spite of myself.
I regained my composure and showed him each problem.
With my pencil and slide rule, he showed how to solve them.

He explained each point fully, and worked them so quick,
I hardly suspected that this was St. Nick.
Soon he had finished and was ready to go,
I had almost forgotten how he'd startled me so.

He whistled his reindeer to come inside.
And through the window they flew, I had left it open wide.
He jumped in his sleigh and drove into the night,
And with the speed of a comet, he was soon out of sight.

I looked at the place on my desk where he'd been
And gazed at my papers again and again.
Santa indeed is a great engineer,
For who else could develop the flying reindeer.

Reprinted from the U.P. Engineer

Thin Shell Structures

(*Continued from page 32*)

Future of Thin Shells in the United States

At an October, 1963 World's Conference on Shell Structures in San Francisco where more than 700 engineers, architects and builders assemboled from all over the globe, it was predicted that an expanding worldwide bull market for thin shells was in the making.

The United States, being a technologically advanced nation, will probably surge ahead in this field since the design of shell structures is now as easy for the expert engineer as any other kind of structure. The increased knowledge of digital computers has greatly reduced the previously burdensome stress calculations and now make the thin shell more competitive in the construction field. Also, there is usually an increase in the aesthetic value of a building which is roofed with a shell such as a hyperbolic paraboloid or barrel vault as compared to an ordinary flat roof.

Future of Thin Shells Abroad

As mentioned previously, thin shells are already quite common in Europe where material costs are generally higher priced than labor costs. There is likewise an increased tendency in such countries as Africa, where the same labor situation exists, to construct new buildings with shell roofs that have such features as "north lights" to give artificial light without letting the intense heat of the sun shine into the building.

A Bright Future Seen

It seems very probable, then, that thin shells will assume an increased role in the worldwide construction field due to their low material costs and aesthetic value. As nations tend to become more technically advanced, shells will become more and more common for single story building construction.

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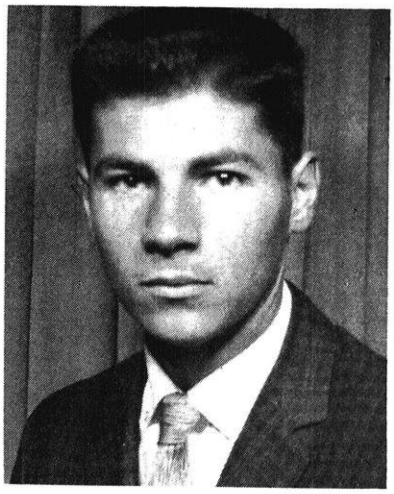


Dallas, a senior in civil engineering at the University of Wisconsin, is interested in structural engineering design. His outside activities include the ASCE, Chi Epsilon, and Tau Beta Pi.

Ultrasonics

(Continued from page 28)

vided abrasive grit and water continually pass between the tool and the work-piece. The ultrasonic vibration is produced by magnetostriction.

The tool is made of soft material, and it must be made the exact counter part of the finished surface that is required. But the tool, being soft, is relatively easy to produce with standard equipment—even in complex shapes. If the tool is required to make a deep cut it is generally advised to employ both a roughing and finishing tool to produce a more accurately finished part.

The dimensions of the cone that connects the transducer to the tool are important for proper amplification but need not to be held to closer tolerances than ±0.001 in. The bond between the tool and cone, however, is critical. In most instances, the stress at this point will be extremely high so silver solder is generally used.

The metal removal rate depends largely upon the amplitudes of vibration of the tool. Large amplitudes produce large accelerations of the abrasive particles and facilitate the flow of the abrasive. Other factors which determine the cutting rate include type and size of abrasive and the physical properties of the material being worked. As a general rule, cutting rates decrease with the toughness of the material.

The actual metal cutting is done solely by the abrasive grit. As was mentioned, large amplitudes produce large accelerations. By Newton's law, F = MA, it may be seen that large forces may be obtained even though the mass particles are, in themselves, very small. The striking force of this abrasive grit chips the metal being worked. By choosing the proper grit, frequency, and feeding pressure, high tolerances can be achieved.

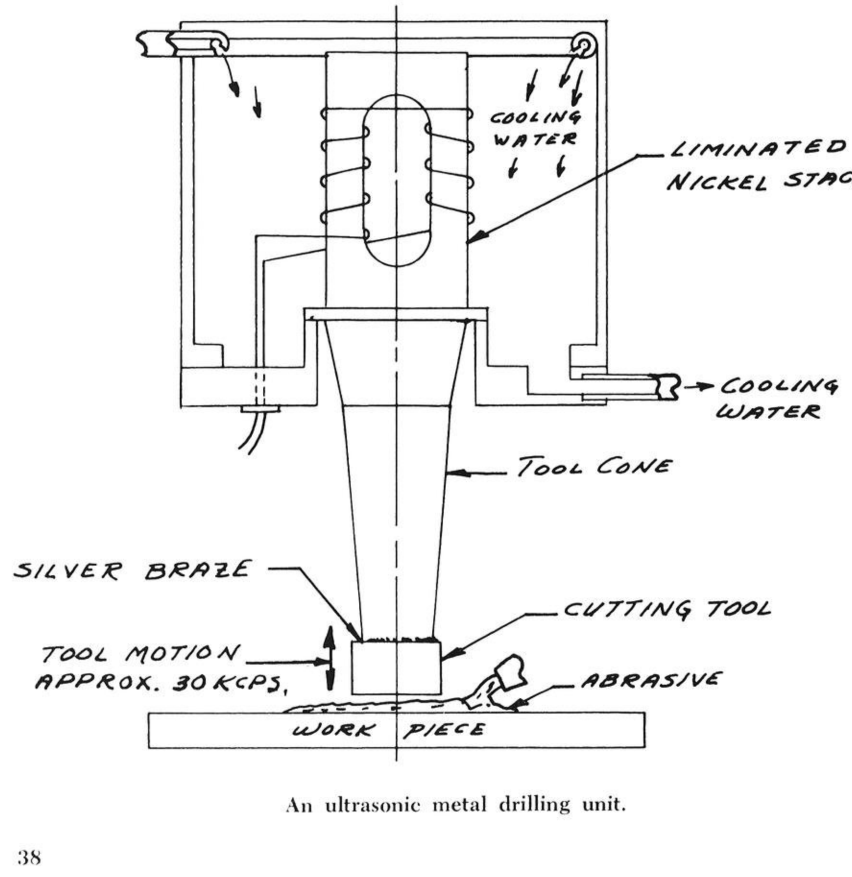
REMOVAL OF SMOKE FROM INDUSTRIAL STACKS

Ultrasonic oscillations have a peculiar phenomenon about them in that they are capable of both coagulating and dispersing aerosols—fine solid particles in gas or air. This fact, along with the improvement of the ultrasonic siren, has proven to be an excellent team in filtering industrial smoke stacks.

The siren, operating at optimum frequencies for coagulation (10–20 kcps), causes the small dust particles to collide with each other forming a larger mass which may then be filtered by ordinary means. That is, the ultrasonic sound itself does not do the filtering but merely increases the particle size. But despite the fact that ultrasonics mainly leads only to the enlargement of the particles with the subsequent necessity for settling a large mass of these in ordinary filters, the purification of smoke from industrial stacks, especially in large cities, is of considerable importance, and the application of ultrasonic methods of cleaning in this and in a number of other circumstances has irrefutable advantages.

OTHER APPLICATIONS

Ultrasonics has many other applications that are just as useful as those that have been mentioned. Among them are underwater signaling, wall thickness measuring, welding, soldering, plating, deburring, tool sharpening, and dental drilling. In time, as the techniques and advantages of ultrasonics become more generally understood, no one doubts that ultrasonics will become even more useful.



An ultrasonic metal drilling unit.

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TOWARD YOUR **B.S.** DEGREE

Dedicated to the principle that in order to be a good Engineer a person must know a little bit about everything. In this section expect to find anything ranging from the history of Zoroastrianism to how to select a wedding ring.

SHAVING THROUGH THE AGES

No wonder "ugh" was probably the first syllable ever spoken; Stone Age man had to resort to clam shell tweezers or sharpened flint "razors" to keep his face smooth. Some 30,000 years later, "ughs" became obsolete as stainless steel razor blades came into vogue.

THOUGH stainless steel shavers and razor blades are the newest items to enter into the battle of the beard, men of 2500 B.C. in Cyprus used tweezers to remove their whiskers—a tedious operation and not without a little pain.

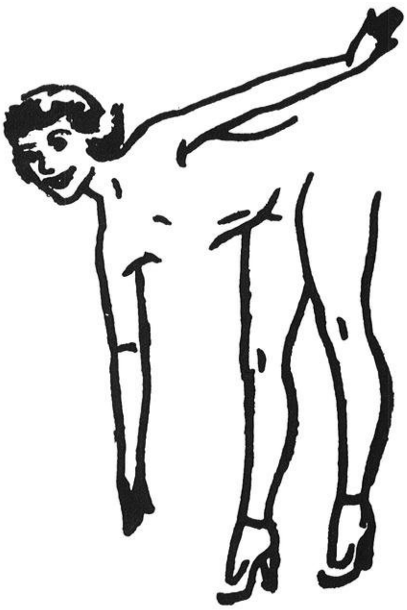
The hair on your face is four times as thick as the hair on your head, from 700 to 800 hairs per inch. To make shaving even tougher, the whiskers don't stand up straight. Their angle is from 30 to 60 degrees, and under the chin they may be nearly flat.

If you are average, you will spend 139 full days during your life shaving off a total of 27½ feet of whiskers! All in all, Americans spend five million man-hours every day just shaving.

We've used everything from sharpened clam shells to polished flint to shave with. Even today, shark's teeth are used in Polynesia. The first barbers, who were also surgeons, used stone razors.

The ancient Egyptians invented a bronze straight razor; many of

(Continued on page 41)



Fill in your Own Lines

She was a young and beautiful bride,
From eating green apples she cried;
Within the lamented
The apples fermented,
And made cider inside her inside.

* * *

"Doctor," said the sick man, "the other doctors seem to differ from you in their diagnosis of the case."

"I know," replied the physician cheerfully, "but the postmortem will show that I was right."

* * *

De-Fun-itions

Gymnasium: Limber camp.
Love letter: Noose paper.
Wedding shower: Start of a reign.
Photo finish: When she returns your picture.
Gossip: One who takes in rumors.
White lie: An attempt to color the truth.
Alimony: War debt.
Snub: Slight mistake.
Diet: Breadth control.

* * *

Swifties

Chronic ailments can become chronicle.

Sudden fame is a short lived flame.

Those looking down at their inferiors have none.

Shorties

Two heads may be better than one—but not in the same house.

Cheer up! The more it costs the more trading stamps you get!

Women rule the world by remote control.

It's not hard to tell a wise man—he thinks that you are intelligent.

You wonder how the other half lives—when you ride in a car with them.

Calory fighters spend too much time fraternizing with the enemy.

The thing to do for that ringing in your ears is to pay your bills.

The severest fines are paid by those exceeding the feed limit.

* * *

Wife to husband: "I wish you had the spunk the government has. They certainly don't let being in debt keep them from spending."

* * *

Give a man enough rope and he'll claim he's tied up at the office.

* * *

Not long ago a business executive passed away and his widow was inconsolable. She cried for a week without stopping. Then a lawyer appeared with a check from the insurance company. She looked at the amount—$75,000—sighed, and with a tear in each eye told the attorney, "Believe me, I'd give $25,000 of this to have him back."

It's a sure sign that a boy is growing up when he starts wanting to play with dolls!

* * *

Is it because Doctor thinks I'd be lonely
Here in his waiting room all by my only,
That whenever he asks me to be here at two
He also asks you, you, you, you and you?

* * *

Staying at the office late to play poker with his friends, the meek little man suddenly realized it was 2 a.m. With a gleam of inspiration, he telephoned his wife and dramatically shouted: "Don't pay the ransom—I've escaped!"

* * *

"How did the explosion occur?"

"The boiler was empty and the engineer was full."

* * *

Moore had occasion to reprimand his wife.

"I think, dear," he said soothingly, "that you fib a little occasionally."

She immediately became indignant.

"Well, I think it's a wife's duty," was her response.

"Wife's duty?" he echoed, wondering what was coming.

"Yes, to speak well of her husband occasionally," came the reply.

(Continued on page 41)

Toward Your B.S.

(Continued from page 39)

these razors, found in Pharaoh's tombs, have sharp edges even today! While iron and steel eventually replaced bronze in the straight razor, men continued to shave with substantially the same type of razor for hundreds of years—with many a nick and scratch along the way. It wasn't until 1762 that anyone got lathered up enough to invent a razor that was "safe."

Jean-Jacques Perret, a master cutler in Paris, contracted skin diseases from going to the barber's shop and being cut about the face—so he conceived the idea of adding a wooden guard to a straight razor, basing his invention on the principle of the carpenter's plane in which only a short section of the blade projects from the surface. But his razor was too expensive for the ordinary man.

Safety razors somewhat resembling their usual modern form with a guarded blade set across the handle were devised by William S. Henson of London in 1847. According to his description, Henson's razor "resembles somewhat the form of the common hoe."

However, Henson's new razor had one drawback: he used a small hollow-ground blade, which had to be fixed in a separate holder for stropping. King C. Gillette, of Boston, found the solution in 1895 when he proposed to mass produce blades of the wafer type so cheaply that they could be thrown away when they were no longer sharp.

Gillette started production of his blades in 1901, and in less than twenty years, the safety razor had become the predominant tool for personal shaving. Wafer blades are now made from continuous strips of steel, each weighing 30 pounds and long enough for 12,000 blades. About 1200 tons of steel go into the making of razor blades each year in the U.S.

With the invention of the Schick Dry Shaver by the late Lieutenant Colonel Jacob Schick, an entirely new technique was introduced to the art of shaving. Today, Schick electric shavers boast cutting heads of surgical stainless steel.

The world's first stainless steel adjustable injector razor was introduced in mid-1962 by the American Safety Razor Company, which 87 years ago produced the first safety razor. One stainless steel adjustable injector razor captured 12 per cent of the total razor market within three months of its introduction.

Stainless steel blades are said to give more than double the life of the ordinary carbon steel type, due to stainless' ability to withstand the corrosive effects of skin oils and water. A special plastic coating on each blade reduces friction and enables the highly-sharpened edge to move smoothly over your face.

Ever wish you didn't have to shave? If you were given the chance to be whisker-less the rest of your life, you'd probably pass up the opportunity! According to a group of eminent New York City psychologists, a man's beard is very important to him symbolically. In a test survey, a number of men were given this hypothetical question: If a cream were offered for sale at a reasonable price which in three applications would rid you of your beard forever so that you would never need to shave again, would you buy it?

The response? Practically none of the men was interested. One of the meager three per cent who did show any interest explained, "It would be O.K., because I've got hair on my chest."

Fill in your Own Lines

(Continued from page 4)

During a fervent revival service at the local church, a lovely young lady seated in the balcony became so wrought up with the spirit of the occasion that she leaned out too far over the rail and fell. The hem of her dress happened to catch on the chandelier and she was held suspended in mid-air.

The thoughtful minister cried out, "Any man who dares look will be stricken blind!"

And a fellow in a front seat said to his friend, "I'm going to chance one eye."

* * *

And as they say in mechanics—"Every couple has its moment!"

* * *

"Does your wife economize?"

"Oh, yes; we have to do without practically everything I need."

Jones: "How do you spend your income?"

Smith: "About 30 per cent for shelter, 30 per cent for clothing, 40 per cent for food and 20 per cent for amusement."

Jones: "But that adds up to 120 per cent."

Smith, "That's right."

* * *

"I don't seem to make any sense out of this poem."

"You're not supposed to. It's meant merely to give you a feeling of emotion. Doesn't it do that?"

"Yes, it makes me sick!"

* * *

Lizze: "Gus is an awful pest. He never seems to know when to stop."

Hulda: "That's strange; I was out riding with him last night and he found a dandy place."

* * *

Cocktail party chatter: "Don't take another drink, honey. Your face is getting blurred."

Playing golf keep me fit."

"Fit for what?"

"Fit to play more golf."

* * *

Dr. ——— was lecturing to his 9:00 o'clock class on the virtues of being awake.

"I've found that the best way to start a day is to exercise for five minutes after arising, breathe deeply, and finish with a cold shower. Then I feel rosy all over."

Just then a sleepy voice was heard to mutter from the back of room. "Tell us more about Rosy."

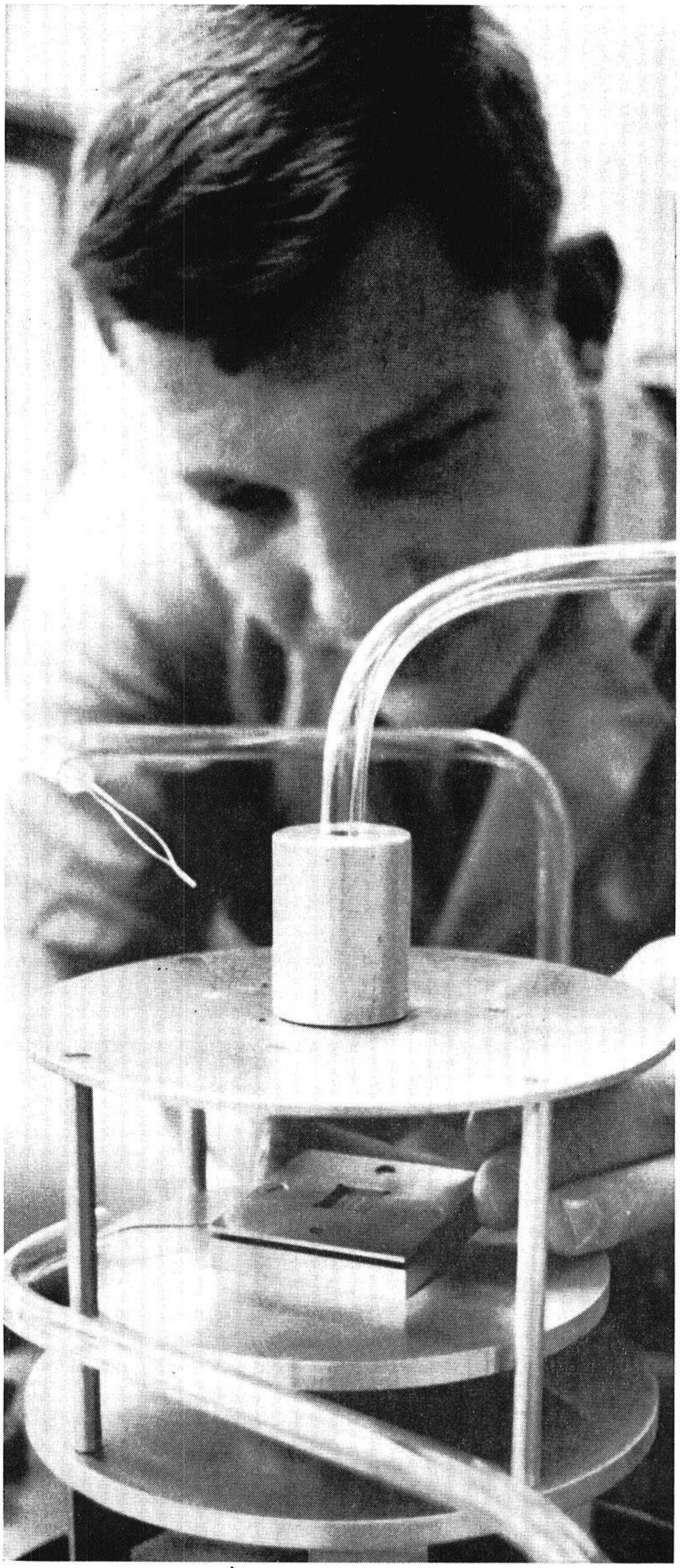
* * *

The new watchman at the observatory was watching a professor using the big telescope. Just then a star fell.

"Begorra," he said to himself, "that fella sure is a crack shot."

* * *

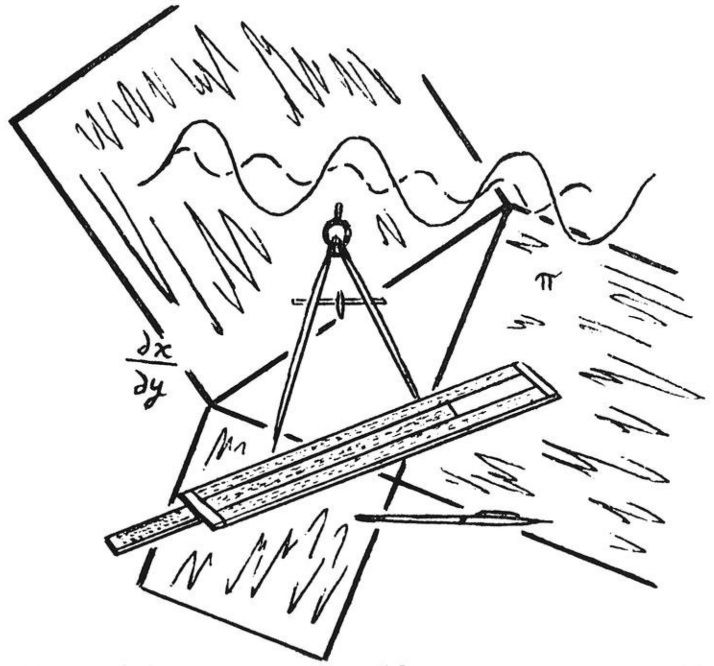
"O. K., Moses, take out your tablet and number from one to ten, we're going to have a little quiz."



THE

MENTAL MAZE

By Clifton Fonstad, Jr., EE'65



IT'S hard to predict how difficult the Mental Maze will be each month but just to be safe—to give more readers courage to fight through the maze—let's start this month's maze with a story. When you're working through the Mental Maze and everything seems to go wrong, remember the saga of William Shanks. Mr. Shanks, many years ago, spent two decades calculating the value of pi. He was doing a fine job and got a value to 707 places. Unfortunately, there was an error discovered after the 528th place. And, you think you've got all the bad luck.

So let's get started on the first puzzle—the first turn in this month's Mental Maze.

1. To begin with here's a question to test your numerical reasoning. Actually the answer isn't as hopeless as it seems. The integer 844,596,301 is the 5th power of what number?

2. Now for a legitimate puzzle. In view of the many ways money seems to disappear, money puzzles should offer few obstacles, so see if you can discover the solution to the following transaction:

A friend of mine went to have a check cashed but evidently the teller misread the check for he handed out the amount of the dollars in cents and the amount of cents in dollars. When his error was pointed out he became flustered and made an arithmetic error so that he gave my friend only one dollar, one dime, and one cent more. Still this was incorrect so after the teller had calmed down he corrected his errors by doubling the amount my friend had already received.

How big was the check? (There is a unique solution.)

3. Last month's proof that O = 1 unfortunately had a flaw in it. This month we've got a new proof so, unless something goes wrong, mathematics has finally been unmasked as a total hoax. You had better look the proof over:

Notice that

$$1^2 = 1$$
$$2^2 = 2 + 2$$
$$3^2 = 3 + 3 + 3$$

And

$$n^2 = n + n + \, . \, . + n \text{ (n terms)}$$

Differentiate and we find,

$$2n\,dn = (1 + 1 + \, . \, . + 1)dn$$
$$= n\,dn$$
$$2 = 1$$

4. Let's try a quicky. If a cat and a half can kill a rat and a half in a minute and a half, how long will it take one cat to kill 60 rats?

5. Here's a problem that should provide a challenge to you. We received a report that Tioga Tech. (Clark County) installed an escalator in their new engineering building. Some of the students wanted to know how many steps were visible at any one time so one of their professors suggested this procedure:

"If one of you, say you, Art, walk up, count the number of steps you take from bottom to top. Another one of you, say Jim, start with Art but walk just half as fast. Just watch Art and take one step every time he takes two. You then can tell how many steps are visible at one time."

If Jim reported that he took 21 steps and Art counted 28, how many steps are visible?

ANSWERS: Again this month you are invited to send your solutions and comments to me—Clifton Fonstad, Jr., % *Wisconsin Engineer,* 333 Mechanical Engineering Bldg., Madison, Wisconsin. Copy for this month's Mental Maze had to be in before any indication of response was available from the November issue, but details of a possible solution competition will be ready in next month's Maze. Now for last month's answers:

1. 4. Instead of using 1 as a unit, 6/5 would be the unit.

2. 4 cows, 31 chickens.

3. It was his own portrait.

4. I *under*stand you're *under*taking to *over*throw my *under*taking.

5. $1/x\,dx - 1/x\,dx = 1$ is correct but each integral would have a different constant of integration connected to it so they can not be canceled.

6. The staff will make it, in fact they could have gone four miles further. What is involved in the solution is a maximum use theory. You want to carry and store no more gas than is necessary to reach the goal. You work backwards and calculate steps that (1) leave you just enough gas at each depot for the next step, (2) involve as few trips as possible, and (3) leave an empty tank when you return to the original depot of each step.

An Interview with G.E.'s J. S. Smith, Vice President, Marketing and Public Relations

Mr. Smith is a member of General Electric's Executive Office and is in charge of Marketing and Public Relations Services. Activities reporting to Mr. Smith include marketing consultation, sales and distribution, marketing research, marketing personnel development, and public relations as well as General Electric's participation in the forthcoming New York World's Fair. In his career with the Company, he has had a wide variety of assignments in finance, relations, and marketing, and was General Manager of the Company's Outdoor Lighting Department prior to his present appointment in 1961.

For more information on a career in Technical Marketing, write General Electric Company, Section 699-08, Schenectady, New York 12305.

COULD YOU OUT-THINK A COMPETITOR?

Consider a Career in Technical Marketing

Q. Mr. Smith, I know engineering plays a role in the design and manufacture of General Electric products, but what place is there for an engineer in marketing?

A. For certain exceptionally talented individuals, a career in technical marketing offers extraordinary opportunity. You learn fast what the real needs of customers are, under actual industrial conditions. You are brought face-to-face with the economic realities of business. You participate in some of the most exciting strategic work in the world: planning how to out-engineer and out-sell competitors for a major installation.

Q. Sounds exciting. But I've worked hard for my technical degree. I'm worried that if I go into marketing, I won't use it.

A. Don't worry—you'll use all the engineering you've learned, and you'll go on learning for the rest of your life. In fact, you'll have to. You see, the basic purpose of business is to sense changing customer needs, and then marshal resources to meet them profitably. That means that you must learn to know each customer's operations and needs almost as well as he understands them himself. And with competitors trying their best to outdo you, believe me—every bit of knowledge and skill you've got will be called into play.

Q. Is that why you said you wanted "exceptionally talented people"?

A. Technical marketing is not everybody's dish of tea. It takes great personal drive and energy, and a talent for managing the work of others in concert with your own. It takes flexibility . . . imagination . . . ingenuity . . . quick reflexes . . . leadership qualities. If you're nervous with people or upset by quick-changing situations, I don't think technical marketing's for you. But if you are excited by competition, like to help others solve technical problems, and enjoy seeing your technical work put to the test of real operation—then you may be one of the ambitious men we're looking for.

Q. Now what, actually, does a man do in technical marketing?

A. Let me describe a typical situation in General Electric. A field sales engineer is in regular contact with his customers. Let's say one of them makes an inquiry, or the sales engineer senses that the time is right for a proposition. With his field application engineer, he determines the basic equipment needed. Then he contacts the marketing sales specialist in the G-E department that manufactures that equipment. The sales specialist, working closely with his department's product engineers, specifies an exact design—realistic in function and cost. Then the sales engineer and his supporting team try to make the sale, changing and improving the proposition as they get cues from the competitive situation. If the sale is made—a very satisfying moment—then the installation and service engineers install the equipment and are responsible for its operation and repair. With the exception of the product design engineers, all these people are in technical marketing. Exciting work, all of it.

Q. In college we learn engineering theory. How do we get the sales and business knowledge you mentioned?

A. At General Electric, a solid, well tested program of educational courses will quickly advance both your engineering knowledge and your sales capacities. But perhaps even more important, you'll be assigned to work with some of the crack sales engineers and application and installation men in the world, and that's no exaggeration. A man grows fast when he's on the sales firing line. As a FORTUNE writer once put it, the industrial sales engineer needs "that prime combination of technical savvy, tactical agility, and unruffled persuasiveness." Have you got what it takes?

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