DISCUSSION.

MR. MOLESWORTH : (Chairman) :—Those of us who had anything to do with rubber shock-absorbers in the early days would have been very glad of some of this information then. I think that some of the gentlemen who are here and are rubber experts can discuss the matter better than I can, and I have much pleasure in calling upon Dr. Stevens.

DR. STEVENS (Consultant to the Rubber Growers Association) :—I am indebted to your Secretary for the invitation to this meeting, and an advance copy of the paper, which has enabled me to go through the different points beforehand and to prepare a few remarks on the subject of rubber.

I know nothing about aeronautics, but I know a little about rubber. Now rubber thread, as used for the purpose under consideration, is what we honestly refer to as pure rubber mixing, and nothing else. We have experience with regard to this kind of mixing, because it is the one that has been adopted, I may say universally, for preliminary tests on the various types of raw rubbers. I do not know whether Mr. Rowland is familiar with the work, but a great deal has been done on this type of rubber compound. It is not being done by engineers, but mainly by chemists, because it was necessary to obtain information for the purpose of comparing the various types of raw rubbers. It seems to me, however, that for the particular purpose in hand this type of rubber is unsuitable. It is difficult to manufacture, and very sensitive to the conditions of vulcanisation, and deteriorates quickly. It also requires very little load to elongate two or three hundred per cent.

Now, in order to get over the difficulties experienced with this type of rubber compound, it is covered with woven thread, and the function of the cover is, I am given to understand, to provide a wearing surface and a protection against light, and also to hold the threads at the desired initial strain. Now, these results could more easily be obtained by a suitable compounding of the rubber. I notice that the lecturer says in one place that compounded rubbers are not suitable, as they show a very much greater fatigue effect. I think that statement is probably too sweeping; it depends so much on the compounding ingredients employed.

I have brought with me a lantern slide showing some load-stretch curves on different types of compounded rubber. (See Fig.) This diagram is taken from a paper which I contributed on Rubber for the Colloidal Reports. The great advantage of putting in a compounding ingredient, like carbon black, into rubber, is that you protect it from the light.

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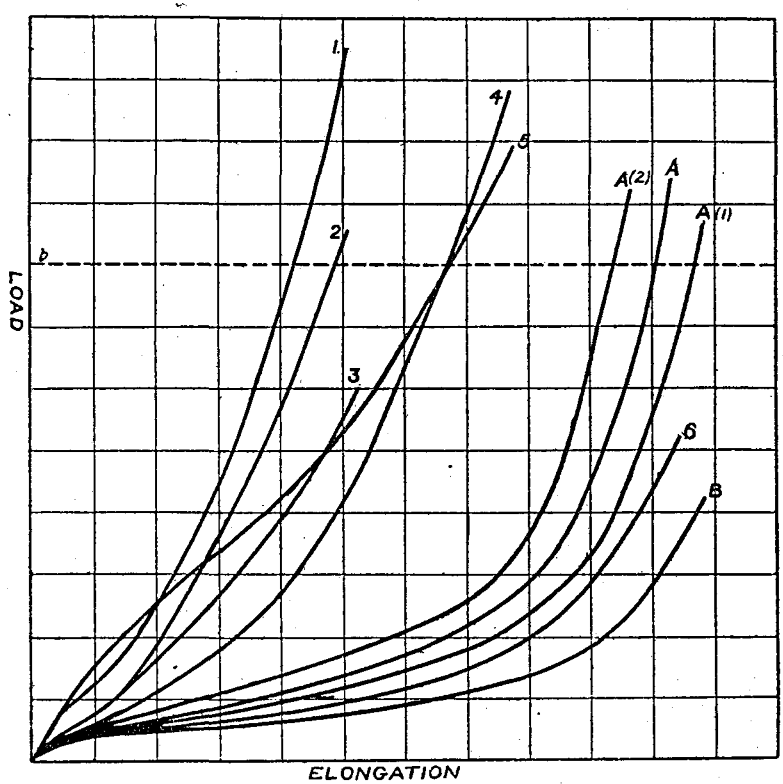

Dr. Geer, of the Goodrich Rubber Co., has described a series of ageing tests for rubber. These or similar tests are universally used. He was the first to describe them in detail. The method consists in testing portions of the rubber and then ageing other pieces in an electric oven kept at 700° Cent. or thereabouts. After which the tests are applied and the difference in the figures is a measure of the deterioration produced.

With regard to the effect of sunlight, and so forth, if you compound the rubber with only a small quantity of carbon black, say 5 per cent., you will get almost complete protection from the effect of sunlight.

I have carried out, also, experiments with raw rubber. A piece of raw rubber sheeting is converted into a sticky mass in a few hours by sunlight. One-half per cent. of carbon black will protect it for weeks, and two per cent. will protect it for a very long time. Putting the rubber in an inert vapour will protect it, but there are simpler methods. It was noted some years ago that

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if rubber was kept in a jar over kerosene oil it was protected to a large extent. I carried out many experiments on these lines, and found that even a moist atmosphere has a protective action.

With regard to the tensile-testing appliance for thread. I think the method described by Mr. Rowland, of using little drums, was worked out something like ten years ago by Schopper, of Leipzic, who constructed a machine for testing rubber thread in this way. Possibly the machine differs in detail from Mr. Rowland's, but the principle was the same.

Mr. Dowty :—I have carried out comparative tests on compression and tension rubbers, and compression rubbers give a bigger hysteresis than tension rubbers. The tests were carried out in each case with gradual loading. The results are, perhaps, no indication of an actual landing when the load is applied suddenly, but there being a bigger hysteresis under such tests, it is probable that this is also true in an actual landing. I do not consider that the hysteresis considerations are of much importance in machines using a dashpot to absorb the energy and working independent of the springing. The efficiency of the rubbers in absorbing energy in hysteresis only occurs when the rubbers are required to absorb the energy as well as provide a springing.

It is usual with tension rubbers to put an initial tension in them, so that when the machine is standing there is only little deflection. If too large a deflection is permitted the machine will be sloppy during taxi-ing. It is necessary to have the tension placed in the rubber during manufacture, for if one relies on placing the initial tension in the rubber by binding it on in place, it is not practicable to obtain the same tension on each side of the undercarriage. Undoubtedly, the best type of tension shock absorber is the braided ring type, with quite a high tension placed in it during manufacture.

The lecturer has shown some interesting graphs giving deflection of rubber in inches against load in pounds. I would suggest that the most convenient and useful form for the undercarriage designer to have this data would be to express these values as "Deflection as percentage of original length" and "Stress in pounds per square inch on original area."

I thank Mr. Rowland for a very interesting paper.

Mr. H. Savage :—There are several points on the paper which touch upon one's experience in other manufactures.

Not being familiar with the construction of these cords, I do not recognise the designation of the sizes (20s, etc.) of the various threads.

In other manufactures extensions exceeding those mentioned in the paper are met with.

Several years ago I experienced the difficulty of holding test samples of rubber, and devised an eccentric disc grip, and have used it for about 20 years.

A somewhat similar disc is used by the U.S. Bureau of Standards at Washington.

Many of the points mentioned relative to hysteresis are well known to rubber manufacturers.

With regard to braiding, I assume that a number of rubber threads are twisted together and used as a cord.

The " braiding tension " is mentioned several times. I assume this means the tension on the rubber threads passing through the braiding machine, but has the tension on the individual cotton threads in the machine any effect on the finished cord?

The machine illustrated is a type brought out about 20 years ago. It may still be in use, but there are at least two later designs that might perhaps be used with advantage. Speaking therefore as one who has met with similar problems in connection with allied manufactures, I should like to thank the author for his interesting paper and the opportunity of inspecting the specimens.

MR. HOWARD FLANDERS :—How many pounds of energy can you absorb in one pound of rubber?

I am of opinion that steel springs would be much lighter than rubber, because it is so much easier to fit them.

Has Mr. Rowland tried ordinary coal gas for protecting rubber? It would be much easier to keep rubber cord in coal gas than in a vacuum.

The only other point is that I have found that replacing steel springs for rubber was a good thing with regard to hysteresis. I have had much trouble from undercarriages which simply broke from the jointing. One particular rolling test smashed the undercarriage after the pilot had shut off his engine. After replacing with rubber the undercarriage was quite stable.

DR. THURSTON :—Knowing nothing about the subject, this lecture has been most fascinating to me.

It seems to me that the function of shock absorbers is to give the maximum stretch possible with the maximum amount of hysteresis to absorb the load so that you do not get a rebound.

The very beautiful diagrams which have been shown this evening demonstrate that rubber is a material having a greater extension than, perhaps, any other, and that it has this remarkable property of absorbing the energy which we put into it.

In various experiments which you can make with corded strands, it is very interesting to note the amount by which the hysteresis can be varied according to the substance surrounding the cord itself. I am quite aware that in the ordinary way it is extremely difficult to increase the hysteresis, but I should like to ask Mr. Rowland if he has made any experiments, either by compounded strands of various grades or by compound rubbers, in order to get the relative motions between the various parts. There are many circumstances in which an increased hysteresis of the cord would be of use, and it is certainly of interest as to what to do to reduce the hysteresis to a minimum, so that when you use rubber for motive purposes you can obtain as much energy out of it as possible.

The experiments relative to the ageing of rubber from exposure to air and light struck me as being most interesting. Certainly it is desirable that we should know as much as possible about the various effects of light and atmosphere upon rubber.

If it is found with rubber, as it is with many forms of fabric, that ultra-violet rays have a bad effect, then it is easy to guard against that, not by putting on a cover, but by coating it with some substance which absorbs the ultra-violet rays, while perhaps being perfectly transparent to the ordinary rays of the sun. During the war many experiments were carried out with regard to fabric, and rubber is very similar. Regarding those experiments which the lecturer has made, in enclosing rubber in vacuum tubes, I should like to know whether he kept them in the dark, or if he exposed some in vacuo to sunlight, and others in vacuo in various degrees of moisture. I know nothing about the subject, and am only speaking because the subject is so fascinating and so valuable that one feels one ought to try and do something.

MR. ROWLAND'S REPLY TO THE DISCUSSION.

In reply to Dr. Stevens I might explain that the whole of our experimental work has been done from an engineering point of view, and as we can claim to be pioneers in the manufacture of shock-absorber cord, we had to obtain our own data. At the outset we realised that in order to produce efficient cord it was necessary to obtain accurate data with regard to the mechanical properties of rubber thread of the correct section. We therefore decided to experiment without reference to standard works, and the general results obtained are in close agreement with those obtained by rubber experts on sections other than square.

With regard to the use of rubber giving a load-extension diagram approximating more closely to the straight line, we believe that it would be a decided disadvantage. The effect of a load-extension diagram, as shown on Fig. 1, is to reduce the average impact load as compared with the straight-line diagram.

This is very noticeable at the early stages of impact, where the load increases very slowly with extension and so provides a valuable cushion effect. The average load effect is apparent from the form of the equations to the two curves.

That for Fig. 1 is :—

$$x = 1.168\,y + 2.05 \sin^{-2} \times 34.58\,y.$$

where x is the extension and y the load. The equation for a rubber giving an approximate straight line is

$$x = \frac{y}{a}$$

where a is a constant depending on the degree of vulcanisation.

By these equations it is clear that the nearer the approximation to a straight line, the higher will be the average load. Since the average stresses induced during landing are directly proportional to the average load, everything is to be gained by keeping that load as small as possible, hence we believe that the present form of load-extension diagram is the best for shock-absorber cord.

We have experimented with a grade of rubber giving a load-extension curve similar to that shown by Dr. Stevens, i.e. a steeper curve with less curvature.

This rubber had an admixture of carbon black with the result that the tensile strength and hysteresis loss were increased, the maximum extension was decreased, and the average load increased. An aircraft firm stated that this rubber was unsuitable for shock-absorbing purposes.

It was also found that a ring made of this rubber, when exposed under load in India, completely perished in a short period of time, whereas a similar ring, made of the usual rubber, and exposed in the same place under the same conditions, was quite sound after a very much longer period.

With regard to the testing of rubber thread, we believe that this is one of the most important factors in the production of efficient cord, but the actual rubber thread to be used in the cord must be tested, and not merely samples or specimens of thread of other sections.

With this object in view, Mr. A. Turner has designed a thread-testing machine, which is very convenient and accurate, and with the aid of this machine we can make a set of rings of uniform tensile strength.

With regard to the initial strain on the rubber mentioned by Mr. Dowty, this is about 1.8 for ordinary cord made to specification 2F.16, but in the case of rings, it is possible to work the rubber at much higher values. This initial strain is controlled by the load to be carried at a definite extension, generally 100 per cent., but we are often asked by aircraft manufacturers to make rings to carry a definite load at 20 to 30 per cent. extension. The methods of manufacture are such that it is possible to vary the initial tension in a ring so that it will give 300 to 400 per cent. extension at one extreme, and semi-rigid at the other.

With regard to the equal tension on both sides of the undercarriage, I am afraid that it would be a difficult condition to obtain with ordinary cord. It is possible for two lengths of $\frac{5}{8}$-inch diameter cord to differ by 30 lbs., and yet both would be within the specified values. Should the weaker cord be applied to one side and the stronger to the other, the standing load would cause the plane to tilt as well as induce unequal stresses during impact. In the case of rings, the variation in tensile strength can be kept within 1 per cent. The stress-extension diagram suggested by Mr. Dowty would no doubt be more convenient for most purposes as compared with the load-extension diagram, and we shall construct such a diagram and forward him a copy when ready.

In reply to Dr. Thurston regarding the increase of hysteresis, the only way we have done this is by increasing the initial strain on the rubber. It would no doubt be possible to obtain this increase by increasing the internal friction between the strands, but it would have the serious disadvantage of fraying the surface of the rubber thread, and so materially decrease its tensile strength. In a well-made cord, there should be no relative movement of the strands.

In our vacuum V air-ageing tests, all our specimens were exposed to the direct rays of the sun, which we find to be one of the most severe conditions. For ordinary ageing test we expose in a constant current of air, but shielded from the sunlight. We understand that exposure to the ultra-violet ray has been tried with some success, and we hope to adopt some such method in the near future.

We have not up to the present made any ageing tests on the cotton or twine cover, in fact we have been so engrossed with the rubber that I am afraid the cover has been entirely overlooked. We shall certainly carry out tests for this effect, and we are indebted to Dr. Thurston for his suggestion of a means to counteract the ageing of the cover.

In reply to Mr. Howard Flanders, re the absorption of energy, we estimate that the energy storage capacity of a tempered steel spring is 95 ft. lbs. per cub. inch, and that for rubber is 14,600, so that the capacity of rubber thread is 153 times that of the steel spring.

With regard to the storing of rubber shock absorbers in coal gas instead of a vacuum, we agree that it would be a much better method, provided the same result could be obtained. We shall include this in our future experiments.

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In acknowledging the vote of thanks for his lecture, Mr. Rowland said :—

I wish to say that the whole of this work has been shared by my chief, Mr. A. Turner, who is responsible for the design of the shock absorber ring, and who is one of the foremost experts in the country on braiding machines and processes.

The diagrams and rubber specimens brought by Mr. Rowland were examined with great interest at the end of the meeting.

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