mixtures of naphthalene and diphenyl in proportions from 1 : 1, to 1 of diphenyl : 0.01 of naphthalene.

As a further test the accumulated diphenyl from all experiments, amounting to about 1 kilogram, was distilled in a large flask and the first few cubic centimeters of distillate collected and submitted to the same tests with negative results.

The presence of naphthalene in Rittman, Byron and Egloff's product at atmospheric pressure can be ascribed by the writers only to the fact that those authors used commercial benzene, which doubtless contained toluene. This last on heating with benzene gives naphthalene as shown by Carnellay¹ by passing mixtures of benzene and toluene through a red hot tube.

The specific gravity of the benzene used by Rittman, Byron and Egloff at 15° was 0.879, whereas that of the one we used was 0.881 at 15.5°. The difference is small indeed but it tends to show the presence of some toluene (0.871 at 15.5°) in the material used by those authors.

SUMMARY

I—The thermal decomposition of benzene has been studied at temperatures varying from 500 to 800° C. and atmospheric pressure.

II—The chief products are diphenyl, diphenylbenzenes, carbon and gas. The formation of diphenyl begins at as low a temperature as 500°.

III—No acetylene was found in the gas, which consisted of hydrogen saturated with benzene vapor, and no naphthalene in the decomposition products, tending to show that the thermal decomposition of benzene at atmospheric pressure takes place with the formation of condensation products in which the benzene ring apparently remains intact, or with the formation of hydrogen and carbon.

IV—The effect of rate on the yields of diphenyl has been studied. The slower rates are more favorable to the formation of diphenyl. The optimum temperature is in the neighborhood of 750°. Above that temperature, diphenyl benzenes as well as carbon and hydrogen form readily.

V—The catalytic action of copper, iron and nickel has been studied. Iron and nickel favor the decomposition to carbon and hydrogen. The action of copper is not marked except above 750°, when the formation of carbon is accelerated.

Further work upon these topics is now in progress in this laboratory.

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RUBBER HOSE FOR USE ON AEROPLANES

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The enormous increase in the world's output of aeroplanes during the last three years has rendered important a systematic inspection of materials used in their construction.

One of the materials requiring detailed examination

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is rubber hose, which is held to be the most desirable material for conveying gasoline from the tank to the engine on aeroplanes.

It was found, at the time that a system of inspection for aeroplane materials was initiated in England, that the quality of the rubber being used was quite unsatisfactory. This was probably due in a large measure to the unfamiliarity of the rubber manufacturers with the properties required of gasoline-resistant rubber hose. They appear in some cases to have endeavored to adapt their regular types of material, such as steam- or water-hose, for use with gasoline, with results which were sometimes disastrous to the life of the aeroplane and to its pilot.

The Underwriters' Laboratories of Chicago have published (May, 1914) their requirements for rubber hose to conduct gasoline, and their tests are very thorough. When the hose is to carry gasoline on aeroplanes some modification of the Underwriters' examination seems desirable. Bursting, tensile, and stretch tests on the original hose are described by the Underwriters, and tensile strength is also determined 24 hrs. after gasoline immersion. It may be pointed out that after such a period the rubber recovers, with little deterioration, its original physical properties. It is important to obtain a hose which will show good physical behavior while immersed in gasoline or immediately after removal therefrom. Bursting and tensile tests were given up as specification tests by the writer because, although they furnish helpful information, it was found that they were not adequate to detect tubes which would behave badly towards gasoline when used on aeroplanes.

In drawing up specifications for gasoline-resistant rubber tubing the following tests were carried out, and found to be suitable for controlling the quality of the tubing.

They are intended to amplify and not to supplant the specifications of the Underwriters' Laboratories.

(1) FLEXIBILITY—The tube is bent to a circle having a diameter (D) which varies according to the inside diameter of the tube (d) as shown below:

d	D
Up to $\frac{1}{2}$ in.	8 times d
$\frac{3}{16}$ in. to 1 in.	10 times d
$\frac{1}{16}$ in. to $1\frac{1}{2}$ in.	12 times d
Above $1\frac{1}{2}$ in.	14 times d

The diameter of the tube so bent should not change at any point by more than 10 per cent from its original diameter.

A tube of poor flexibility will show a permanent weak spot if bent sharply a dozen times at the same place.

(2) IMMERSION IN GASOLINE—At first an immersion test of 200 hrs. in cold gasoline of about 0.720 sp. gr. was used. It was found that approximately the same effect can be attained in a shorter time by boiling in gasoline for 1 hr. under a reflux condenser, followed by 24 hrs. standing in gasoline at room temperature. The approximate increase in weight and volume of the sample (about 3 in. long) is recorded for correlation with the results of the other tests. The decrease in bore at the narrowest part of the tube is also noted

and should not exceed 25 per cent, otherwise the supply of gasoline to the engine may be seriously diminished, especially for tubes of less than $1\frac{1}{2}$ in. internal diameter.

The adhesion of the rubber to the canvas fabric must remain good, and the "nerve" of the rubber must not be seriously impaired when examined immediately after the gasoline treatment.

This test for strength of adhesion of rubber to canvas, and for retention of "nerve" of the rubber is open to the objection of being too vague, but it was not found expedient to incorporate standardized tests for these properties, and in actual practice no difficulty was ever experienced in judging whether or not a sample passed the test. This test is also a rough guide to the amount of free sulfur present, crystals of sulfur being deposited from a tube containing an excessive amount.

(3) PERMEABILITY TO GASOLINE—A 14 in. length of the tube is held vertically and plugged with a glass stopper at the bottom. A glass tube is fitted to the top, and is filled with gasoline to a head of 12 in. above the top of the rubber tube, and then loosely stoppered. The length of rubber tube exposed to the action of the gasoline is 12 in. At first the gasoline is absorbed comparatively rapidly by the rubber. The level of the gasoline in the glass tube should not be allowed to fall more than 3 in., additions of gasoline from a known volume being made as necessary. The amount of gasoline which permeates through the walls of the rubber tube is noted during the first and second days, as a guide to the behavior of the sample. During the third 24 hrs., by which time the rate of permeation has become approximately constant, the amount of gasoline passing through the tube should not exceed 100 cc. per sq. ft. of original internal surface of the rubber tube.

(4) DRY HEAT—A piece of the tube is heated for 2 hrs. at 132° C. The rubber should remain elastic after this treatment, and should show no signs of stickiness or brittleness, nor should any surface cracks become visible on stretching the sample.

(5) COLD—The tube is immersed in carbon dioxide snow, which was found to render all tubes brittle while they remained cold. The rubber regains its elasticity on attaining room temperature again, and this test was, therefore, discontinued.

(6) BURSTING PRESSURE—Tests on bursting pressures were carried out before and after the permeability test, but were subsequently given up, as it was found that the quality of the tube could be sufficiently safeguarded by the other tests, and, moreover, the pressure to which the tube is subjected in actual service is very slight.

(7) ACETONE EXTRACT, FREE SULFUR, MINERAL SULFIDES, AND SULFUR OF VULCANIZATION are also determined, and furnish useful information in forming a judgment as to the quality of the specimen under examination. The free sulfur should not exceed 1 per cent of the weight of the finished tube (exclusive of the canvas). Excessive free sulfur will be carried by the gasoline into the cylinders of the engine where it may promote pitting.

(8) ASH—A portion of the rubber is incinerated very slowly, and the amount and composition of the ash determined.

(9) QUALITY OF CANVAS—Tests on the quality and strength of the fabric inserted in the tube were contemplated, but it was found expedient to leave to the judgment of the manufacturer the kind of fabric to be used, relying on the tests already enumerated to control the production of a satisfactory tubing.

When the examination of rubber hose for use with gasoline was commenced, great diversity in construction, composition and behavior was found. Some makers appear to have believed that vulcanized rubber is essentially non-resistant to the action of gasoline, and therefore put as little of it in the tubes as possible. Some tubes yielded as much as 75 per cent ash, while others gave less than 40 per cent. As great a diversity was found in the composition of the ash. Barium sulfate, lead, zinc, calcium and magnesium were found in a great variety of proportions, each manufacturer carefully guarding his own "mixings" and considering them of vital importance for the production of a satisfactory tube. Some typical figures of ash analyses are appended. The figures for total ash are percentages of the finished tube, excluding the canvas.

TABLE I—TOTAL ASH AND ASH ANALYSES OF GASOLINE-RESISTANT RUBBER HOSE

DESCRIPTION OF TUBE	TOTAL ASH Per cent	PERCENTAGES OF				TOTAL ASH	
		BaSO ₄	PbO	ZnO	CaO	MgO	
French No. 1.....	51	26	10	..	26	10	
French No. 2.....	42	20	..	5	34	20	
British 1-A.....	72	43	3	4	..	21	
British 1-B.....	73	44	35	4	..	4	
British 1-C.....	45	51	34	5	1	1	
British 1-D.....	45	40	..	5	33	13	
British 2-A.....	49	..	47	..	5	37	
British 2-B.....	39	10	18	27	26	..	
British 2-C.....	38	..	37	..	4	34	
British 2-D.....	43	19	18	3	26	4	
British 2-E.....	39	..	27	..	5	46	
British 3-A.....	68	..	36	34	5	..	
British 3-B.....	41	..	..	24	25	25	
British 4-A.....	45	46	..	29	4	10	
British 4-B.....	60	72	..	7	12	1	
British 5-A.....	59	28	6	7	31	..	
British 6-A.....	44	..	40	13	2	29	
British 7-A.....	61	..	60	8	..	3	

French No. 1 was not a very good tube. The rubber was somewhat harsh. The tube failed to pass the flexibility test, but was satisfactory for permeability. The adhesion between rubber and canvas at the end of the immersion test was fairly good, but the tube contained as much as 3 per cent free sulfur. The heat test caused obvious deterioration in the quality of the rubber. Barium sulfate and lime are the chief mineral ingredients.

French No. 2 was inferior to No. 1. The rubber was harsh, and its behavior varied along the length of the consignment, indicating probable uneven vulcanization. Mechanical defects, such as local pitting, were to be seen. The adhesion of rubber to canvas after immersion appeared at first sight to be very good, but this was due rather to the ease with which the rubber itself tore. Lime and magnesia are the most prominent minerals, with barium sulfate as a diluent. Rubber hose for use with gasoline on French aeroplanes is required to contain 45 per cent mineral matter with a margin of ± 5 per cent, 50 per cent rubber with the same margin, and to have a density of 1.6 (± 0.1).

British 1-A to 1-D, though all from the same maker, show wide variations in total ash and in the composition of the ash. The bad feature of both 1-A and 1-B was the weakness of the adhesion between rubber and canvas. Separation of the plies occurred spontaneously under gasoline. The other properties of these tubes were satisfactory. 1-D was a good tube.

British 2-A to 2-E, all made by one firm, show less variation in total ash, but much variation in the composition of the ash. 2-A and 2-B represent respectively outer and inner rubber layers of the same tube. The same applies to 2-C and 2-D. The inner layer of rubber proved to be of better quality for use with gasoline than the outer layer. The adhesion between rubber and canvas was bad. Tubes 2-A and B showed high constriction of the bore. All of these tubes contain a considerable quantity of lead, and 2-E is noticeably high in magnesia.

British 3-A and 3-B—3-A showed bad "adhesion;" 3-B very good adhesion, though the rubber was rather "short" after the immersion test.

British 4-A and 4-B—The product of this firm showed great variability in bore-constriction, but the flexibility, permeability, adhesion after immersion test, and quality of rubber after immersion test were all good.

British 6-A was a good tube. *British 7-A* was too harsh.

A large number of other tubes were examined, but most of them showed defects in one or more of the properties tested. Some manufacturers used a certain amount of reclaimed rubber or of rubber substitute, but it is believed that this is not desirable as regards the quality of the product, although it lowers the cost.

One firm made an excellent tube by the use of 45 per cent Para rubber. The mineral ingredients in this tube were lead, calcium and magnesium. This tube withstood the immersion test with hardly any deterioration in the "nerve" of the rubber, and the adhesion between rubber and canvas was scarcely affected. The bore constriction after immersion test was less than 25 per cent on a $1\frac{1}{2}$ -in. tube, and all of the other tests gave good results.

It is probably undesirable to use less than 40 per cent rubber.

In many cases it was customary to insert a spiral of brass or steel wire in the bore of the tube so as to improve its flexibility. This practice is unnecessary if the walls of the tube are made fairly thick, and in the case of the brass spiral constitutes a possible source for the entry of copper into the rubber.

It was found that a decided improvement in some of the properties of gasoline-resistant rubber hose could be achieved by changing the manner in which the canvas was inserted. The usual method was to friction the canvas with a very thin layer of the rubber mixing, so that in the finished tube there were virtually three plies, an inner layer of rubber, a middle layer of canvas, usually from 2 to 4 turns according to the size of the tube, and an outer layer of rubber. When a tube made in this manner is subjected to the immersion test the three layers expand at different rates, resulting often in spontaneous separation. The canvas layer expands hardly at all, and so the expansion of

the inner layer of rubber is forced inwards, with consequent constriction of the bore. A better method of construction consists in spreading a definite layer of rubber on the canvas, so that in the finished tube the thickness of rubber between each turn of the canvas is at least twice as thick as the canvas itself. A cross-section of a tube made in this way shows the canvas to be distributed as a spiral through the whole thickness of the wall of the tube. Such a tube shows improved flexibility and better behavior under the immersion test, there being less tendency to separation between rubber and canvas and a smaller constriction of the bore. For tubes up to $\frac{5}{8}$ in. internal diameter, two turns of canvas are sufficient. Between $1\frac{1}{16}$ in. and $1\frac{1}{4}$ in., three turns are desirable, and for tubes larger than $1\frac{1}{4}$ in. internal diameter 4 turns of canvas should be used. The larger sizes are used for oil or water.

The inner layer of rubber on all tubes for carrying gasoline should, of course, be seamless. A seam on the inner rubber would facilitate penetration of the gasoline to the canvas, which would then function as a wick for the distribution of gasoline throughout the wall of the tube.

A satisfactory material for protecting a cut end of tubing from absorption of gasoline may be made from a mixture of about 4 parts gelatin with 1 part glycerin, with the addition, if desired, of a small quantity of formaldehyde or potassium bichromate. Such a solution might even be run, while warm, through the whole length of the rubber tube, so as to form a protective film on the inner surface. Rubber hose for gasoline is, however, now being made in Great Britain of a quality sufficiently good to need no protective film, and there is, moreover, the possibility of portions of such a film becoming detached and causing partial choking of the tube. When the hose is not to be cut the ends may be best protected from absorption of gasoline by being capped.

In testing a large consignment, a sample should be taken from at least every 100 ft. in order to guard against lack of uniformity in quality, such as would be caused by uneven vulcanization or variability of the mixing.

In storing gasoline-resistant rubber hose the usual precautions should be taken for protection from strong light, and from extremes of temperature. As a matter of safety a tube should not be used which is more than 6 months old.

The testing of rubber hose for use with oil or hot water on aeroplanes is less important. Rubber hose for use with oil should withstand 8 hrs.' immersion in castor oil at 100° C. without serious injury to the quality of the rubber, and without any disintegration of the tube. The increase in weight after thoroughly wiping off the oil should be less than 5 per cent. Rubber hose for use with hot water should withstand boiling in water.

The writer had the privilege of being associated with Mr. W. E. Gibbs and Mr. N. W. Barritt in carrying out the work described in this and in the following paper.

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