

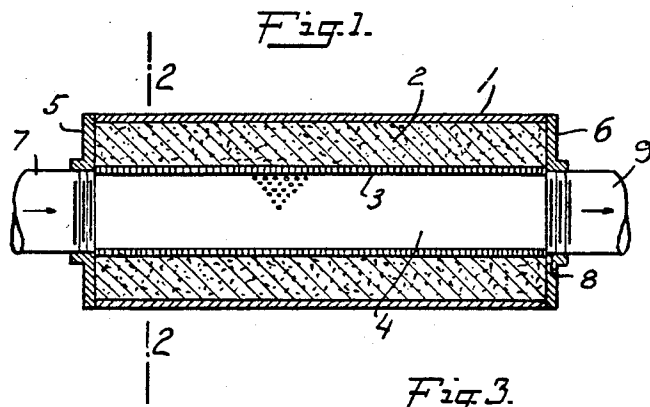
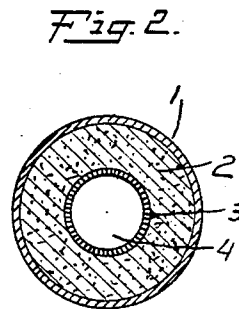
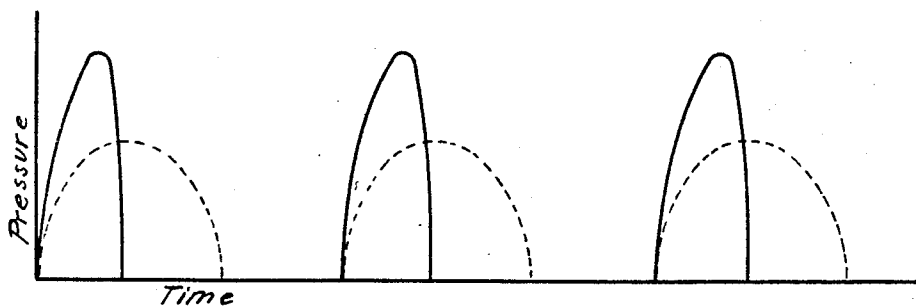
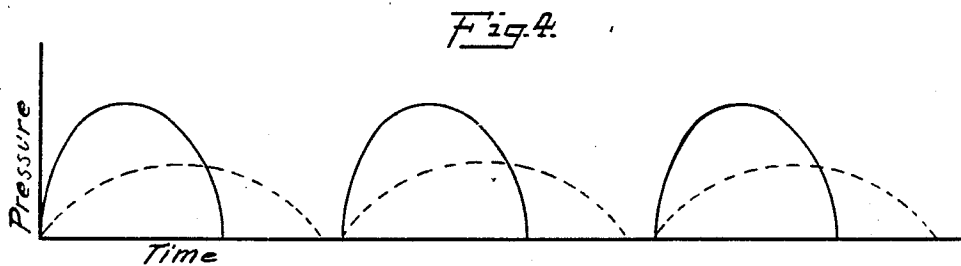
Aug. 8, 1933.

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MUFFLER

Filed Nov. 8, 1929



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106 — 75

Patented Aug. 8, 1933

vermiculite

surface No. 5102

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XR

UNITED STATES PATENT OFFICE

1,921,468

MUFFLER

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Application November 8, 1929. Serial No. 405,658

10 Claims. (Cl. 137—160)

My invention relates to a gas-pressure absorbing and sound absorbing composition of matter suitable for use in constructing mufflers for noise-producing gases and more particularly for the
5 expanding and noise-producing pulsating gases that are discharged from internal combustion engines. My invention relates specifically to an improvement in the gas-pressure absorbing and sound-absorbing material used in such mufflers.

10 It is an object of my invention to provide a gas-pressure absorbing and sound absorbing material that is efficient, light in weight, cheap to construct, is not affected by moisture, high temperatures, or oxidizing conditions, and does not
15 disintegrate when subjected to the pulsating action of exhaust gases when used in gas engine mufflers. The gas-pressure absorbing and sound absorbing material of my invention is particularly adapted for use in conjunction with the
20 type of muffler described and claimed in the Frederick H. Schnell application Serial No. 361,376, filed May 8, 1929, now Patent No. 1,811,762, of June 23, 1931. This type of muffler will be more fully described hereinafter in connection
25 with the description of my invention.

The explosion within the cylinder of an internal combustion engine creates tremendous pressure therein. The steam or vapor in the cylinder
30 of a steam engine is also under very high pressure. Upon the opening of the exhaust port the gas emerges at high velocity in the form of a "slug" of gas very quickly reducing the pressure in the cylinder. By the word "gas" I mean to
35 embrace both gas and vapor. The result is a succession of pulses or slugs of gas at relatively high pressure travelling through the exhaust manifold or pipe or any other type of exhaust system at a high velocity. Upon the emergence
40 of these gas pulses or slugs into the atmosphere an additional spurt in velocity is probably acquired by reason of expansion, and a sharp sound results. The greater the pressure gradient between the pulse of gas and the atmosphere the
45 greater the velocity and the sharper the sound. In order to successfully silence exhaust noises the muffler must suppress compression peaks and thus even the flow of the escaping gas pulses to the point where a sound is not created. In
50 addition the sound communicated to or generated within the muffler should be silenced. These sounds may originate at various places in the exhaust system.

My co-worker, Frederick H. Schnell, in pending application Serial No. 361,376, filed May 8,
55 1929, describes a muffler for absorbing the gas-

pressure peaks and sound of gas engine exhausts without appreciably increasing the back-pressure on the engine. In this device, the exhaust gases are passed along the surface of a gas-pressure absorbing and sound absorbing
60 material such as mineral wool, metallic wool, crushed mineral matter, mica, exfoliated vermiculite such as zonolite, blown slag, coke, pumice, or other porous aggregates and built-up units of such aggregates. For silencing blow-off gases,
65 air compressor intake and exhaust noises, and noises produced by gases at room temperature, flammable gas-pressure absorbing and sound-absorbing materials such as wool, cotton, or other
70 cellulosic fibers may be used. The built up units may be faced with a foraminous retaining wall which may be of perforated sheet metal. Such a wall is necessary with granular or other loose
75 fillers in which a binder is not used to cement the particles together. I have found that it is possible to make an excellent muffler material suitable for use in the Schnell construction by cementing certain granular materials and especially exfoliated vermiculite into a mass so that
80 it will absorb sound and suppress gas pressure peaks.

In view of the fact that every material which is not a perfect reflector of sound is to a degree an absorber of sound it would probably be well to
85 draw some sort of a specification for the term "sound-absorbing material" as that term is used in the present case. In all acoustic data the sound transmitted by an open window is used as
90 a standard of comparison. The ratio of the sound absorbed by an area of a material to that transmitted by an equal area of an open window is called the absorption factor or value of that material.

If a material one square foot in area absorbs one-fourth the sound transmitted by one-square
95 foot of an open window that material is said to have an absorption factor or value of 25 per cent. In this specification whenever the "sound-absorption factor" or "value" is used in conjunction with an absorbing material or construction
100 in a muffler it is understood that this factor or value is obtained by measuring the absorption of such material or construction in the usual way by means of flat pads and the like,
105 of identical material and construction. This is necessary since it is very difficult or impossible to obtain the factor after the muffler is assembled. In the mufflers of this specification, as the sound-absorption factor of the sound-absorbing material decreases, the size of the muffler must
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metal lined
silica

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increase and a material with a factor of ten per cent or less would probably necessitate an unwieldy size and greatly increase the back pressure of the gases because of excessive skin friction caused by the large area exposed to the gases. Hence in the present consideration by "sound-absorbing material" I do not contemplate a material having an absorption factor of less than ten per cent at 1024 double vibrations per second. Throughout this specification all absorption values are based on 1024 double vibrations per second. For most situations an excellent muffler may be constructed with a material having an absorption factor of 25 per cent or more. For exceptional results it is preferable to use a material having a factor greater than 45 per cent. The absorbing material should be of appreciable thickness for best results. It should be at least one-quarter of an inch thick and preferably one-half inch or more.

In the accompanying drawing:

Fig. 1 is a longitudinal, sectional view of one form of muffler;

Fig. 2 is a transverse, sectional view on line 2-2 of Fig. 1; and

Figs. 3 and 4 are charts which indicate the effect of the muffler on exhaust gases.

Referring to the drawing, the reference numeral 1 designates an outer sheet metal cylinder which is welded or otherwise fastened at its ends to annular metal discs 5 and 6. This cylinder encloses an intermediate annular space 2 packed with the gas pressure absorbing and sound absorbing material to be hereinafter described. An inner cylinder 3 of foraminous rigid material, such as perforated sheet metal, encloses the gas pressure absorbing and sound absorbing material and provides a straight, open, unobstructed duct 4 extending from end to end of the muffler. Because of the high temperature of internal combustion exhaust gases cylinder 3 expands and therefore it preferably is not fastened to either metal disc 5 or 6 or both, thereby forming a slip joint and preventing buckling since cylinder 1 which is also fastened to discs 5 and 6 does not expand as much as cylinder 3. Discs 5 and 6 are provided with central openings which may be threaded to receive inlet pipes 7 and discharge pipes 9, respectively. It is usual in automobile mufflers to provide slip joints so that these pipes are free to move in the central openings of the discs and such construction may be employed in place of the threaded connection shown. The arrows in the drawing indicate the direction of gas flow. It is preferable to have the internal diameter of cylinder 3 of the same size as pipe 7. If the diameter of the duct is smaller it increases the back pressure. The gas pressure absorbing and sound absorbing composition of my invention fills the annular space 2 lining the outside of duct 3. The foraminous lining may be omitted, the absorbing composition thereby forming the walls of the duct.

As hereinbefore explained, a series of gas-pressure peaks emerges at high velocity from pipe 7. Each peak tends to expand in all directions. The gas and pressure waves freely pass through perforated cylinder 3 and enter annular space 2. The property of the perforated sheet metal of permitting the free transmission of gas and sound therethrough, together with its other advantages, makes it the preferred foraminous material for a device of this character. The perforations may vary in size and shape. Because of lower manufacturing costs circular

openings are preferred. Holes suitable may vary from approximately 0.080 to 0.125 inches in diameter but the sizes are not limited to these dimensions. For most purposes the holes are evenly distributed throughout the area of the sheet metal although such even distribution is not necessary. The holes are present in sufficient number so that their total area represents from 2½ per cent up to 35 per cent of the area of the sheet metal though fair results may be obtained with holes having an area as low as 1 per cent of the area of the sheet. The shape, size and distribution of the perforations all have an influence on the ease with which gases and sound pass through the sheet of metal. The holes should be small enough so that the absorbing material will not work its way out through them when the muffler is in service. Excellent results are obtained when the ratio of the unperforated portion of the metal forming such facing to the openings therein is such that a substantially continuous surface is exposed to the sound waves and gas pressure waves. In such cases the average dimensions of the individual openings are usually less than the distance between the edges thereof. Tests show that a muffler containing absorbing material faced with a stiff perforated sheet, the perforated area of which is as low as 2½ per cent of the area of the sheet with holes about .075 inch in diameter, absorbs as much sound as and has a muffling efficiency equal to a similar muffler in which the perforated facing is omitted, except when an automobile is coasting. It is possible to omit the perforated metal facing or other foraminous facing by constructing a molded annular or other suitably shaped absorbing material as hereinafter specified as by bonding sized crushed mineral particles together at their points of contact to form a porous mass. Such a molded gas-pressure absorbing and sound-absorbing material has an opening therethrough corresponding to the foraminous tube.

The improved gas-pressure absorbing and sound absorbing material of my invention comprises a built-up unit of discrete particles of aggregates and binder. The aggregate may be formed of the exfoliated vermiculite, known to the trade as zonolite. The particles of aggregates may be of any suitable mineral filler and porous particles such as crushed coke, particles of bloated clay and pumice may be employed. The particles are sized, preferably passing through a three mesh screen and remaining on a 10 mesh screen, so that they form a porous mass when packed into a container as in the muffler. If the particles are not bound together they will tend to fail by abrasion with each other because of the vibration produced by the conditions of use. To overcome this abrasion the particles are bound together chiefly at their points of contact by a binder such as a soluble alkali silicate and especially sodium silicate. A low melting point silicate such as glass may be used or the particles may be heated to such a temperature that they are bound together at their points of contact. For internal combustion engines the binder should be of heat-resisting material.

I have found that an exfoliated vermiculite called zonolite, is especially suitable as a gas-pressure absorbing and sound absorbing material when bound together into porous mass. Its lightness is a decided advantage. The ver-

miculite need not be exfoliated completely and may comprise a mixture varying from small particles of separate leaves of vermiculite to large pieces of aggregates of partially or wholly exfoliated product. Such aggregates are much lighter in weight than the original mineral but do not disintegrate readily due to the cohesion between the leaves. A typical screen analysis of such material known as "furnace run" follows:

10.6% retained on a screen of $\frac{1}{2}$ " mesh.

11.3% will pass through a $\frac{1}{2}$ " mesh screen and be retained on a 3 mesh screen.

29.4% will pass through a 3 mesh screen and be retained on a 6 mesh screen.

31.8% will pass through a 6 mesh screen and be retained on a screen having openings $\frac{5}{64}$ " in diameter.

16.9% will pass through a screen having openings $\frac{5}{64}$ " in diameter.

The material may range over a considerable range of sizes and should be selected for the service to which it is to be subjected. For ordinary mufflers for automobile engines I prefer exfoliated zonolite which has been screened so that most of the product will pass through a 3 mesh screen and remain on a 10 mesh screen. Experiment has shown that the muffler absorption depends mainly upon the air spaces between the particles. The bonding agent should be of sufficient rigidity and strength to space the particles without filling the voids. Further conditions to be met by the bonding agent in internal combustion engine mufflers include ability to withstand heat, the leaching effect of water, the chemical action of exhaust gases, and the vibrations of engine explosions, engine vibrations, and road shock.

The particles of aggregate may be molded and baked into a porous body and then inserted into the muffler container. For the muffler of Fig. 1 the absorber preferably would be molded into the shape of a cored cylinder. In another method the wet mixture of aggregate particles and binder is tamped into annular space 2 between the outer shell and inner perforated shell and then baked into place. A 1:1 mixture by weight of furnace-run zonolite and 3.25 to 1 ratio sodium silicate solution of 42° Bé. weighing about 28 pounds per cubic foot after packing or tamping gives excellent results. The mixture is then dried and if sodium silicate is used it is baked preferably at above 450° F. The above ratio may be varied considerably and the resulting baked product may vary from 8 to 36 pounds per cubic foot. When the more closely sized zonolite is used about 0.9 part of sodium silicate is used to 1 part of zonolite. The silicate, in drying, loses approximately 50 percent of its weight. Finely divided limestone such as dolomite mixed with the silicate gives extra strength to the bond. The zonolite and binder are distributed in heterogeneous arrangement to form pores or cells of more or less uniform size and distribution, just enough binder being used to cement the particles together. The above 1:1 mixture weighing 28 pounds per cubic foot when tamped will have about 83 percent of voids after drying. The actual limits vary widely from this figure and may vary from as low as 70 percent and be as high as 95 percent. The space occupied by the actual particles in annular space 2 is therefore 5 percent to 30 percent.

When sodium silicate is used as the binder,

a small amount of soap or a fatty acid saponifiable by sodium silicate may be added to it with beneficial results. The soap affects the surface tension of the binder, so that it does not spread as much over the surface of the particles of aggregate thereby concentrating the binder at the points of contact. Less than one per cent of soap based on the binder content is sufficient. It may also be advantageous to add shredded paper or other combustible material to the mix. This material is then burned out and leaves the product more porous.

The gas-pressure absorbing and sound-absorbing portion of the muffler therefore provides an expansion space for gas pressure peaks and the maximum pressure of the pulse of gas is decreased as the result of the expansion, the pressure waves being longer and lower in intensity. Fig. 3 shows in solid lines a hypothetical diagrammatic representation of several gas pulses as they enter the muffler and in dotted lines is a similar representation of the same pulses after expansion has taken place. The pressure wave characteristic has become flattened. It is probable that a second phenomenon takes place within annular space 2 to further flatten the wave characteristic. Relatively speaking, the rapidly moving gas enters the annular space 2 in the form of a succession of rapid compressions and rarefactions. The compressions are suppressed and merged together by the choking effect of the walls of the tiny pores or cells with a resulting reduction of the intervening rarefactions. Fig. 4 shows in solid lines the pressure wave characteristic corresponding to the dotted curve of Fig. 3. The dotted lines of Fig. 4 show the pressure wave characteristic after the gas has undergone the choking action of the porous gas-pressure absorbing and sound-absorbing material. The porous material offers practically no resistance to the fairly steady flow of the gas stream through the straight and unobstructed duct 4 and especially if duct 4 is made of smooth perforated, sheet metal, it facilitates the flow with the net result that there is practically no resistance to the gas flow and little or no back pressure is built up aside from that due to surface friction. The absorption of the gas-pressure peaks by the absorbing material, and consequent smoothing out the gas flow and eliminating the noise made by the gas slugs when emerging into the atmosphere, is an important feature. The sound-absorbing material is used for this double function of absorbing sound and gas pressure peaks without appreciably increasing the back pressure.

It is probable that some noise is generated at the end of pipe 7. This noise is silenced by the sound-absorbing material. It is not projected longitudinally of the duct 4 since sound does not project itself in single directions to form rays. It emanates in all directions unless it encounters reflecting surfaces. Foraminous cylinder 3 allows this sound to pass freely therethrough and it is thereafter absorbed by the material in annular space 2.

Mufflers which are considered satisfactory and used by automobile manufacturers, show by acoustimeter measurement, a total muffling efficiency of at least 55 per cent when the internal combustion engines, for which the mufflers were designed, are run at full load. A muffler for an automobile engine which has a muffling efficiency at full load of 75 per cent is exceptional.

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Although the muffling efficiency of satisfactory mufflers for automobiles is only 55 per cent at full load, it must be recognized, that in cities where this efficiency should be high, automobile engines practically are never run at full load. Under light loads, characteristic of city driving, the efficiency may be well over 95 per cent. Even on country roads where high speeds may be attained, automobile engines are seldom subjected to full load. On the other hand, motor boat engines and especially outboard motors, are very often run at full load, so that unless the muffler efficiency is high, that is, above 95 per cent, the exhaust noise is excessive. This noise is heard for a long distance over the water and therefore is objectionable. The ordinary outboard motor muffler, although seemingly inefficient, has an efficiency of from 75 to 90 per cent at the sacrifice of some power due to back pressure. Stationary internal combustion engines and others which are run so that they are well loaded, usually must be equipped with high efficiency mufflers.

The efficiency of the muffler is determined by measuring the noise generated by the gases escaping into the atmosphere with and without muffling. The muffler efficiency should be determined when the muffler is used with the engine for which it is designed. This is essential since the size, shape, amount of absorbing material and other variables of the muffler are determined for each of the various sizes and types of engines.

I claim:

1. In a muffler for a pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a gas-pressure absorbing and sound absorbing, molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a binder, said intercommunicating interstices being open to said gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

2. In a muffler for pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a thin, stiff membrane with a plurality of openings therein, and an exterior lining adjacent said membrane, said lining comprising a gas-pressure absorbing and sound absorbing molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and water glass weighing from 8 to 36 pounds per cubic foot after drying at 450° F., said intercommunicating interstices being open to gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

3. In a muffler for pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a thin, stiff membrane with a plurality of openings therein, and an exterior lining adjacent said membrane, said lining comprising a gas-pressure absorbing and sound absorbing molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and sodium silicate and containing from 70 to 95 percent of voids after drying at 450° F., said intercommunicating interstices being open to gases

passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

4. In a muffler for pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a thin, stiff membrane with a plurality of openings therein, and an exterior lining adjacent said membrane, said lining comprising a gas-pressure absorbing and sound absorbing molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a heat resistant binder, said intercommunicating interstices being open to gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct, and being of such thickness and efficiency that its average sound absorption value is at least 25 percent.

5. In a muffler for pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a thin, stiff membrane with a plurality of openings therein, and an exterior lining adjacent said membrane, said lining comprising a gas-pressure absorbing and sound absorbing molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a heat resistant binder, said intercommunicating interstices being open to gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct, and being of such thickness and efficiency that its average sound absorption value in combination with said perforated facing is at least 25 percent.

6. In a muffler for pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a thin, stiff membrane with a plurality of openings therein, and an exterior lining adjacent said membrane, said lining comprising a gas-pressure absorbing and sound absorbing molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a heat resistant binder, said intercommunicating interstices being open to gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct, and being of such thickness and efficiency that it will produce a muffling efficiency of at least 55 percent when used with a loaded engine for which it is designed.

7. In a muffler for a pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a gas pressure absorbing and sound absorbing, molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a binder and weighing from 8 to 36 pounds per cubic foot after drying at 450° F., said intercommunicating interstices being open to said gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

8. In a muffler for a pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a gas pressure absorbing and sound

absorbing, molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a binder and containing from 70 to 95 percent of voids after drying at 450° F., said intercommunicating interstices being open to said gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

9. In a muffler for a pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a gas pressure absorbing and sound absorbing, molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a binder, a large portion of said vermiculite consisting of particles passing through a three mesh screen and remaining on a ten mesh screen, said intercom-

municating interstices being open to said gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

10. In a muffler for a pulsating, noise-producing gas, a duct for the passage of said gas through said muffler, said duct having a wall comprising a foraminous member and an exterior lining adjacent said foraminous member, said lining comprising a gas pressure absorbing and sound absorbing, molded composition having intercommunicating interstices therethrough, said composition comprising discrete particles of exfoliated vermiculite and a binder, said intercommunicating interstices being open to said gases passing through said duct, said composition not causing any material increase in the resistance to the flow of said gas through said duct.

WILLIAM A. JACK, 3d.

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