

June 6, 1944.

R. L. LEADBETTER

2,350,513

SOUND BARRIER WALL OR DOOR CONSTRUCTION

Filed Dec. 30, 1940

2 Sheets-Sheet 1

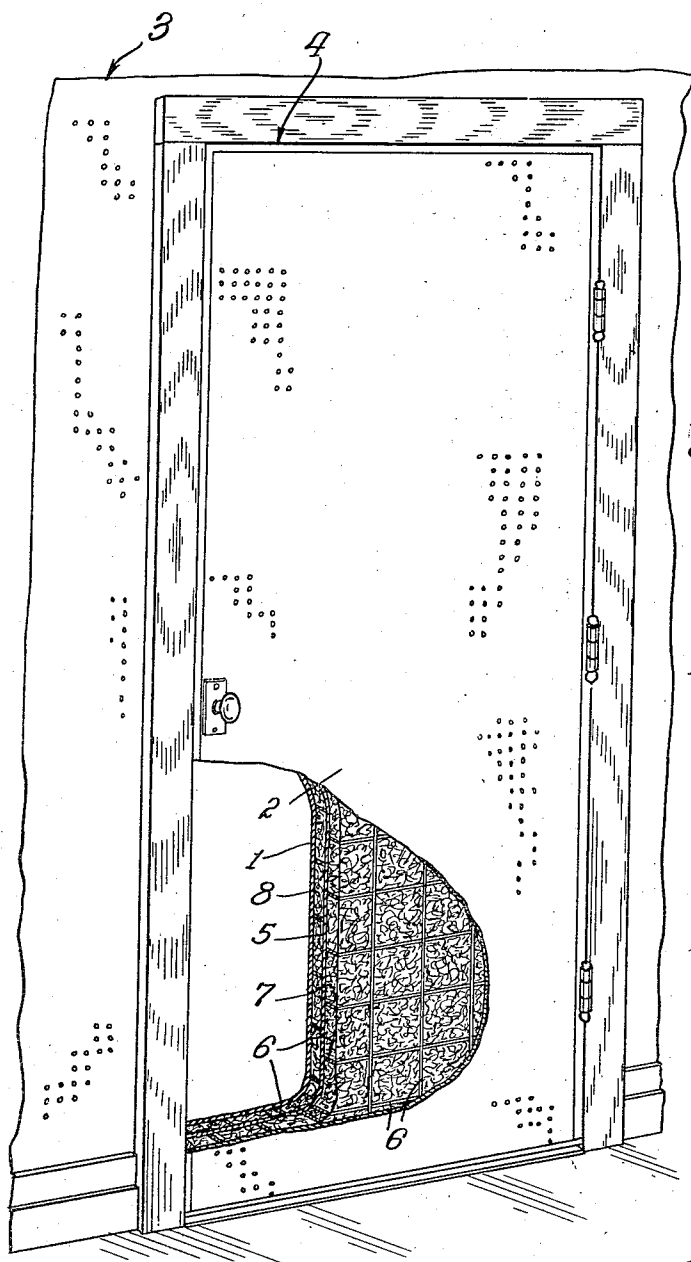


Fig. 1.

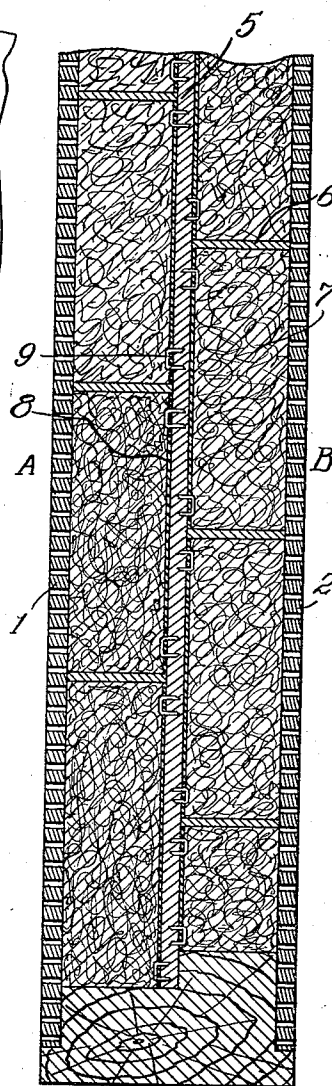


Fig. 2.

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2 Sheets-Sheet 2

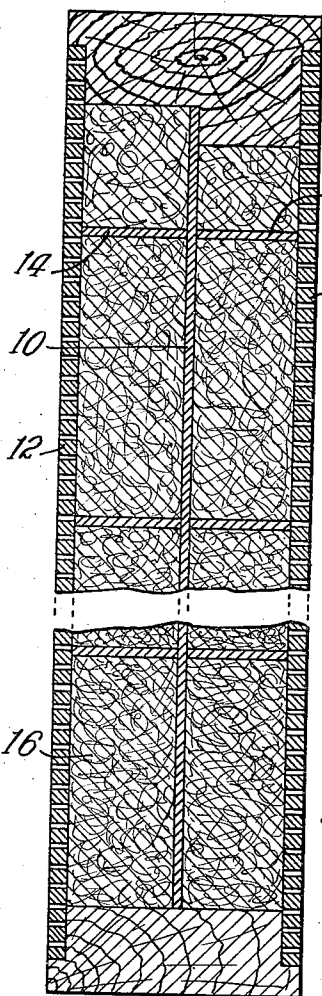


Fig. 3.

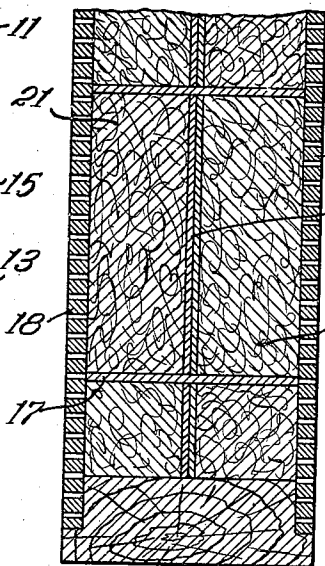


Fig. 4.

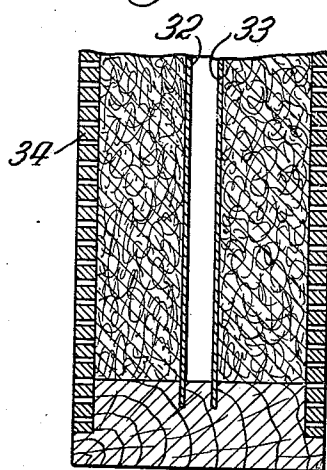


Fig. 7.

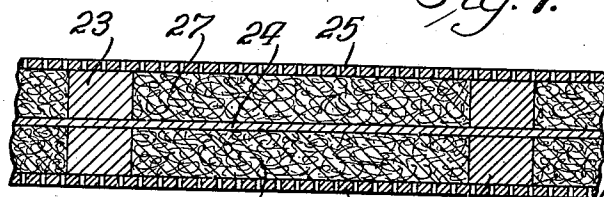


Fig. 5.

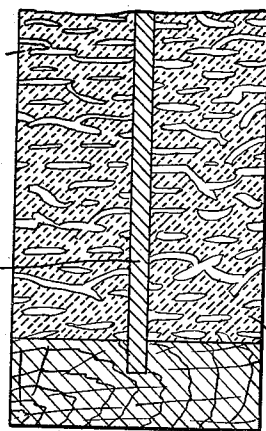


Fig. 6.

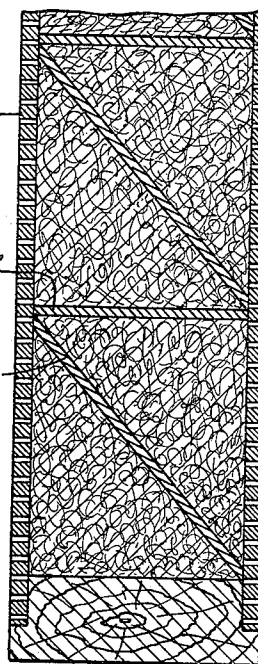


Fig. 8.

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UNITED STATES PATENT OFFICE

2,350,513

SOUND BARRIER WALL OR DOOR
CONSTRUCTION

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Application December 30, 1940, Serial No. 372,310

9 Claims. (Cl. 20—91)

This invention relates to building construction, more particularly to doors and partitions which form barriers to the passage of sound from or into an enclosure such as a room or office.

Sound is the sensation produced by vibrations of air particles at the organs of hearing. The waves which travel from the source of sound to the tympanic membrane consist of alternating zones of pressure (condensations) and partial vacuum (rarefaction). These pressure waves, which are known as sound waves, possess appreciable kinetic energy and are capable of doing work.

Sound waves progressing in an elastic medium, such as air, and meeting an obstacle, such as the partition forming a wall of a room, are either reflected, absorbed and dissipated in the form of heat, or transmitted to structures connected with the obstacle or to the space adjacent the further side of the obstacle. More accurately, such waves are generally reflected in part, and absorbed in part, the remaining energy being transmitted in the form of sound waves or vibrations. As a practical matter, no wall is a perfect reflector of sound, nor is any partition known which will absorb all of the energy of the sound waves incident upon its surface.

It follows from the foregoing that in order to acoustically insulate a room from the space surrounding it as, for example, to prevent the transmission of sounds from one room to an adjoining room through a common partition between them, the partition should be designed to reflect and absorb as much of the energy of the sound waves impinging upon its surfaces as possible. However, since it is generally desirable in such circumstances to minimize the sound level in one or both of the rooms, and since sound reflected from the partition would contribute to the maintenance of an elevated sound level, it is desirable in a sound barrier partition to absorb as much as possible of the sound energy rather than to reflect the sound waves back into the source room.

The primary object of this invention is to provide a sound barrier or insulating partition which will absorb a large part of the energy of the sound waves impinging upon its surfaces with resulting minimum transmission and reflection of the sound. Secondary objectives include the provision of lightweight but stiff and strong doors and partitions having these acoustical qualities.

Unless a partition is pervious to air in such a way that the oscillation of the air particles which

make up the sound waves may continue from one side of the partition through openings therein to the other side, transmission of sound through the partition must be the result of forced vibration of the structure caused by the alternating pressures of the sound waves on the incident side of the partition and resulting in the formation of corresponding alternating pressures on the further side of the partition which, in turn, are manifested as sound waves. Thus, the acoustical energy of the sound waves is converted into mechanical energy of vibration of the structure, the latter being reconverted into acoustical energy by the generation of sound waves in the receiving room. Various devices whereby attempts have been made to minimize the amplitude of such structural vibrations by increasing the mass of the structure as, for example, by the use of masonry walls, or by increasing the flexural stiffness, although effective to some extent, have proved to be generally undesirable from the cost or weight standpoints and necessarily result in increased reflection of the sound waves into the source room. Attempts have also been made to increase the mechanical damping of the vibrating structure to thereby decrease the transmissivity without at the same time increasing the reflectivity of the partition. Hollow walls have been packed with a bulky filling material, such as mineral wool, cotton linters, etc., but such filling material has a tendency to improve the coupling between the wall panels and is therefore ineffective as an acoustic insulating means. In one case, a plurality of spaced non-vibratile damping sheets are spaced between the outer panels of a door.

A relatively complete description of known structural expedients intended to minimize transmission of sound through partitions may be found in the National Bureau of Standards Report BMS 17 entitled, "Sound Insulation of Wall and Floor Constructions," dated March 28, 1939.

The present invention proceeds on the assumption that it is impossible, as a practical matter, to prevent forced vibration of at least some element of a partition or door upon the surfaces of which sound waves impinge. The structure of the invention includes means for (1) minimizing the amplitude of the forced vibrations, (2) damping such vibrations, (3) preventing reflection of sound waves from the partition or door, and (4) absorbing sound within the source room to thereby minimize the sound level therein. A fifth component which is entirely unique with this invention comprises means for mini-

mizing the coupling between the vibrating structure and the atmosphere adjacent the further surface of the partition; that is, means for preventing the generation of sound waves by the vibrating structure within the space adjacent the partition on the side thereof remote from the sound source. The structural expedients intended to perform these various functions are illustrated in the accompanying drawings, in which

Fig. 1 is a perspective view, partly in section, of a portion of a partition and a door embodying the invention;

Fig. 2 is an enlarged vertical section of the door illustrated in Fig. 1; and

Figs. 3-8 are similar sectional views illustrating certain modifications of the invention.

Contrary to the heretofore universal practice whereby the outer panels of walls intended as sound barriers were made as air-tight as possible, all forms of the present invention have apertured surfaces. The surface member may be artificially perforated with sufficient small distributed perforations to render the member pervious to sound, or this member may be composed of a material having sufficient interconnected pores to admit of entrance of the sound waves without substantial reflection thereof. In Figs. 1 and 2 apertured panels 1 and 2 comprise the exposed surfaces of partition 3 and door 4. As is more fully pointed out in Norris Patent No. 1,726,500, a panel which would ordinarily reflect a large part of the sound waves striking it may be made to transmit substantially all of the sound by perforating the panel as shown in Fig. 1. For example, panels 1 and 2 are made sound pervious and suitable for the purposes of the invention by providing them with approximately fourteen $\frac{3}{4}$ inch holes per square inch throughout their areas.

Each form of the invention also includes an air-impervious inner member which is referred to herein as a diaphragm because it may be set into vibration by the action of sound waves. The diaphragm 5, for example, is spaced between apertured panels 1 and 2 and is so mounted within the structure that air particle movement on one side of the diaphragm may not be transmitted to the other side thereof except as a result of the vibration of the diaphragm itself. A stiffening grid 6 of intersecting strips may be cemented in place between diaphragm 5 and apertured panel 1 and another between diaphragm 5 and apertured panel 2, if desired, with definite beneficial results in addition to improved structural strength. It has been found that the increased stiffness limits the amplitude of vibration of the partition or door and for this reason added stiffness is effective in preventing transmission of sound waves. The remaining spaces between the diaphragm and the facing panels are each filled with an intersticed mass 7, materials such as metallic, mineral, or cellulosic wool, ceramic nodules or a ceramic body having intercommunicating pores, exfoliated vermiculite, or the loose fibrous material available under the trade name "Cellufoam" being suitable for this purpose. A material which has sufficient internal strength to support itself and not pack solidly in the lower portions of the individual cavities is preferred. If desired, sheets 8 of asphalt impregnated felt or similar non-rigid, non-vibratile or acoustically "dead" material may be loosely fastened to diaphragm 5 on either one or

both sides thereof as by means of staples 9 or cement applied at several points.

Although experimental investigation has conclusively demonstrated the effectiveness of the above-described partition or door construction as a sound barrier, it is exceedingly difficult to analyze the action and demonstrate the manner in which this desirable over-all result is accomplished. The various data available point to a plausible explanation of the action of the barrier. In order that the invention may be clearly understood, but without limitation to the particular action described, this explanation is given here. It is believed that the intensity of sound waves approaching the side of the partition adjacent the space indicated at A, Fig. 2, is substantially undiminished as the waves travel through the perforations of the apertured panel 1 and the interstices of the filling material 7. The alternating pressures applied to the diaphragm 5 by these sound waves cause the diaphragm to vibrate. The process thus far involves the transformation of the acoustical energy of sound waves into mechanical energy of vibration of the diaphragm. If the structure on the further side of diaphragm 5, that is, on the side adjacent that indicated by the letter B, were omitted, the mechanical energy of the vibrating diaphragm would be reconverted into acoustical energy as sound waves emanating from the diaphragm. However, it has been found that this reconversion is minimized by the presence of the intersticed masses 7 at the further surface of diaphragm 5. Apparently the presence of this filling material prevents the formation of sound waves or at least minimizes their manifestation in the space B. Stated in a different way, the presence of the filling material 7 results in poor acoustical coupling of the vibrating diaphragm 5 with the atmosphere in the space B. It is likely that apertured panel 2 itself contributes in some measure to this decoupling effect.

It should be pointed out that the structure on the incident side A of diaphragm 5 apparently operates in this same manner to prevent return of acoustical energy in the form of sound waves into the space A from the vibrating diaphragm. Once the diaphragm is set into vibration, whether from pressure waves approaching from A or from B, it tends to generate sound waves which would, except for the decoupling structure of the invention, travel in both directions from the two surfaces of the diaphragm. It will thus be seen that the sound levels in the spaces A and B are depressed by the action of the barrier wall because (1) substantially no sound is reflected from the partition back into the source space and (2) substantially no sound is transmitted through the partition from the source space to the receiving space.

The efficiency of the barrier structure may be improved somewhat by providing means for internally damping the vibrations of diaphragm 5 and thus dissipating the energy to some extent. Mismatching and interference between the non-rigid non-vibratile sheets 8 and the diaphragm to which they are loosely applied result in a decreased amplitude of vibration of the diaphragm. Also, the diaphragm may itself be made of a suitable non-elastic material having substantial internal damping qualities, such as ordinary roofing felt. Such materials are referred to herein as non-rigid, non-vibratile materials. It should be recognized that the terms "vibratile" and "non-vibratile" as used herein are relative

terms, it being understood that all materials will vibrate to some extent. The former term refers to such materials as sheet iron, plywood, etc. which tend to sustain vibration when struck and the latter term refers to relatively non-elastic materials which may be non-rigid and acoustically dead, such as asphalt impregnated felt, or which may be rigid, such as masonry panels. In order to further limit vibration of the structure, the stiffening grids 6 are provided. It has been found that such grids increase the barrier efficiency of the partition, particularly in the lower frequency ranges. Staggering of the grids in the manner indicated in Figs. 1 and 2 subdivides the areas of diaphragm 5 between the contacting strips forming the two grids into smaller sections which vibrate with smaller amplitudes than the larger diaphragm areas. In general, the stiffness of diaphragm 5 should be as great as practicable.

Fig. 3 illustrates an alternative barrier structure in which a non-rigid, non-vibratile sheet 10 is hung like a curtain from a supporting rail 11 to form the diaphragm element of the structure. This embodiment of the invention is primarily intended for use in a door or in the fabrication of units which may be arranged edge-to-edge in vertical position as shown in the drawing to form a partition. The mass and internal damping characteristics of this sheet should be as great as practicable. The diaphragm 10 is preferably supported only at its top edge, the side and bottom edges of the diaphragm being in contact with but not affixed to the sides or bottom of the door or unit frame. As in the structure of Figs. 1 and 2, the diaphragm is spaced between exposed apertured panels 12 and 13, stiffening grids 14 and 15 being provided to strengthen the structure and give some support to the diaphragm 10. The grids in this case are in register with each other and grip the diaphragm between them. A suitable intersticed filling material 16 is loosely packed into the cavities between the diaphragm and the apertured panels.

In the embodiment illustrated in Fig. 4, a single grid 17 spans the space between the outer apertured panels 18 and 19. Each cavity so formed is provided with a diaphragm 20 which may be either a vibratile or a non-vibratile sheet, and may, if desired, comprise two or more coextensive sheets in contact with each other. When a plurality of sheets are used, it is advantageous to provide them in different thicknesses, as this results in interference and damping of vibration. These diaphragms should fit snugly between the strips forming the grid 17 but are free to move laterally to some extent so that the coupling between these vibrating members and the grid may be as poor as possible in view of the frictional engagement with the grid. The laminated diaphragm structure resulting from the use of two or more sheets introduces an additional damping factor resulting from interference between the individual sheets and frictional losses resulting from the sliding of the edges of the sheets against the gridwork and of one sheet against the adjacent sheet. As in the other forms of the invention, the spaces 21 and 22 between the diaphragm and the apertured outer panels 18 and 19 are loosely packed with a filling material as described above.

Although the several embodiments of the invention herein described are equally adaptable to partitions or doors, the structure of Fig. 5 is

particularly intended for sound barrier partitions. In place of the usual "two by four" studding, studs 23 may be employed to support an air-impervious diaphragm 24 of plywood or other suitable sheathing. These supporting members also serve as furring strips to which the outer apertured panels 25 and 26 may be fastened. A suitable filling material is loosely packed into the spaces 27 and 28.

In the structure of Fig. 6, self-supporting intersticed bodies 29 and 30 are provided on either side of diaphragm 31. As indicated in the drawing, these bodies may be in the nature of layers of ceramic material having considerable stiffness and interconnected crevices for the entrance thereto of the sound waves. Since the material is self-supporting, separate apertured outer panels are not necessary.

Two spaced diaphragms 32 and 33 are provided in the embodiment illustrated in Fig. 7. In other respects the structure is similar to that of Fig. 5. Suitable spaced furring strips, not shown, may be used to support the diaphragms if they are not in themselves rigid and self-supporting. Also, a set of grids, not shown in this figure, may be used in the spaces between each diaphragm and the contiguous apertured panel.

The structure illustrated in Fig. 8 is similar to that of Fig. 4 except that the diaphragms 36 are arranged diagonally within the cavities between the strips forming the grid 37 and apertured panels 38 and 39. These diaphragms are preferably, although not necessarily, rigid. They may be arranged in parallel orientation, as shown, or alternate diaphragms may span opposite diagonals of the cavities. The employment of such members greatly increases the stiffness of the structure with corresponding substantial improvement in acoustical performance. Furthermore, the diagonal diaphragms tend to diffuse the sound waves and apparently contribute to improve the over-all efficiency of the barrier and provide a more uniform action throughout the audible frequency range.

The operation of the several modified forms of the invention is believed to be similar to that of the embodiment of Figs. 1 and 2 which is fully described above. It will be appreciated that various other modifications of the invention may also be made. Such structures, although not specifically described and illustrated, are intended to be included within the scope of the appended claims.

I claim:

1. A sound barrier wall construction comprising a pair of spaced substantially parallel apertured panels forming the exposed surfaces of said wall construction, an air-impervious diaphragm spaced between said apertured panels in substantial parallelism thereto, a sheet of non-rigid, non-vibratile material adjacent and engaging at least a portion of at least one surface of said diaphragm at a point other than a point of support of said diaphragm, and intersticed masses substantially filling the spaces internally adjacent said apertured panels.

2. The construction of claim 1 in which said diaphragm is composed of non-rigid, non-vibratile material.

3. A sound barrier wall construction comprising a pair of spaced substantially parallel apertured panels forming the exposed surfaces of said wall construction, a non-rigid diaphragm spaced between said apertured panels in substantial parallelism thereto, a grid of intersecting

strips on each side of said diaphragm, each said grid engaging the contiguous surfaces of said apertured panel and said diaphragm and defining cavities therebetween, and an intersticed mass in each of said cavities.

4. The construction of claim 3 in which the grids are so arranged that at least a portion of the strips forming the grid on one side of said diaphragm engage said diaphragm at points between the points of engagement of the strips forming the other grid and said diaphragm.

5. A sound barrier wall construction comprising a pair of spaced substantially parallel apertured panels forming the exposed surfaces of said wall construction, a self-sustaining diaphragm spaced between said apertured panels in substantial parallelism thereto, a sheet of non-rigid, non-vibratile material adjacent and engaging at least a portion of at least one surface of said diaphragm at a point other than a point of support of said diaphragm, and intersticed masses substantially filling the spaces internally adjacent said apertured panels.

6. A sound barrier wall construction comprising a pair of spaced substantially parallel apertured panels forming the exposed surfaces of said wall construction, a diaphragm spaced between said apertured panels in substantial parallelism thereto, a sheet of non-rigid, non-vibratile material adjacent and engaging at least a portion of at least one surface of said diaphragm at a point other than a point of support of said diaphragm, said non-vibratile material being loosely attached to said diaphragm only at spaced

points on the surface thereof, and intersticed masses substantially filling the spaces internally adjacent said apertured panels.

7. A sound barrier wall construction comprising a pair of spaced substantially parallel apertured panels forming the exposed surfaces of said wall construction, a vibratile diaphragm spaced between said apertured panels in substantial parallelism thereto, a sheet of non-rigid, non-vibratile material adjacent and engaging at least a portion of at least one surface of said diaphragm at a point other than a point of support of said diaphragm, and intersticed masses substantially filling the spaces internally adjacent said apertured panels.

8. A sound barrier wall construction comprising a pair of spaced substantially parallel apertured panels forming the exposed surfaces of said wall construction, a diaphragm spaced between said apertured panels in substantial parallelism thereto, a grid of intersecting strips on each side of said diaphragm, each said grid engaging the contiguous surfaces of said apertured panel and said diaphragm and defining cavities therebetween, and an intersticed mass in each of said cavities.

9. The construction of claim 8 in which the grids are so arranged that at least a portion of the strips forming the grid on one side of said diaphragm engage said diaphragm at points between the points of engagement of the strips forming the other grid and said diaphragm.

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