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(54) Fuel injection systems for diesel engines

(57) A fuel injection system for a diesel engine with a DeNOx catalyst comprises a fuel injection pump arranged to produce periodic pressure pulses and at least one fuel injector connected to the fuel pump by a respective outlet assembly (4) and a supply line. The outlet assembly (4) includes a reverse flow damping valve (6, 8) and an unloading valve (2, 24). Disabling means (18, 22; 30; 32, 34) is arranged selectively to reduce or eliminate the reverse flow damping function of the reverse flow damping valve (6, 8).

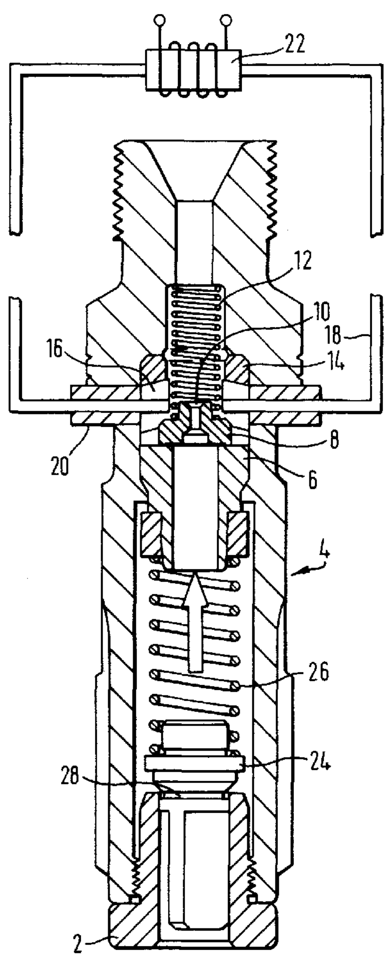

FIG. 1

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Description

The present invention relates to diesel engines, particularly of indirect injection (IDI) type, and is concerned with fuel injection systems for such engines.

IDI diesel engines are those engines in which the fuel injectors are positioned to inject the fuel into the precombustion chambers which communicate with the main combustion chambers by passages through which the burning fuel/air mixture passes into the main combustion chambers of the engine. These engines contrast with direct injection (DI) engines in which the fuel injectors are positioned to inject the fuel directly into the main combustion chambers, e.g. are positioned in the cylinder head to inject fuel into the cylinders.

The exhaust gases of all engines contain a certain proportion of nitrogen oxides (NOx) and these are injurious to health and are increasingly proscribed by law. The NOx emissions from diesel engines are somewhat higher from DI engines than IDI engines and it is known to provide DI engines with a catalyst, referred to as a DeNOx catalyst, in the exhaust path whose function is to chemically reduce the NOx. Such catalysts are well known and typically comprise platinum and/or other catalyst materials which are carried on a suitable carrier or matrix and over which the exhaust gases flow.

It is a characteristic of DeNOx catalysts that they only operate effectively if the exhaust gases also contain at least a certain minimum content of unburnt hydrocarbon material (HC) and this requirement is inherently fulfilled by DI engines under most operating conditions.

The NOx emissions from IDI engines are somewhat lower than from DI engines and it has, therefore, previously not been necessary for IDI engines to be fitted with a DeNOx catalyst. However, exhaust emission regulations are becoming progressively stricter and this fact coupled with the continuing popularity of IDI engines now renders it desirable to fit at least certain IDI engines with a DeNOx catalyst. However, the unburnt HC material in the exhaust gases from IDI engines is typically below the minimum value which is necessary for a DeNOx catalyst to operate effectively, at least under certain operating conditions, and this means that if a DeNOx catalyst is simply provided in the exhaust gas path of an IDI engine it will not operate effectively to reduce the NOx in the exhaust gases, at least under certain engine operating conditions.

Whilst the content of unburnt HC in the exhaust gases of DI diesel engines is generally sufficient for a DeNOx catalyst to operate effectively, it is found that under certain operating conditions the HC concentration in the exhaust gas is in fact not sufficient for the catalyst to operate with its maximum potential efficiency. It is, therefore, desirable, from the point of view of minimising unreduced NOx emissions, to be able selectively to increase the concentration of unburnt HC in the exhaust gases of a DI diesel engine also.

Accordingly it is the object of the present invention to provide a diesel engine, particularly of IDI type, with a DeNOx catalyst, and more particularly to provide a fuel injection system for such an engine, which is such that the DeNOx catalyst can operate effectively under all operating conditions to reduce the NOx in the exhaust gases of the engine.

According to the present invention a fuel injection system for a diesel engine, particularly of IDI type, with a DeNOx catalyst comprises a fuel injection pump arranged to produce periodic pressure pulses and at least one fuel injector connected to the fuel pump by a respective outlet assembly and supply line, the supply line including a reverse flow damping valve and an unloading valve, and is characterised by disabling means arranged selectively to reduce or eliminate the reverse flow damping function of the reverse flow damping valve. The invention also embraces a diesel engine with a DeNOx catalyst and a fuel injection system of the type referred to above.

Conventional fuel injection systems comprise a rotary fuel injection pump connected to the fuel injectors of the engine by respective supply lines. The pump supplies pressure pulses to the supply lines sequentially which results in the associated fuel injectors injecting fuel into the associated inlet ducts at the appropriate times. When the pressure in each supply line drops below the threshold pressure at which the fuel injector operates, injection of the fuel is terminated but subsequent pressure waves and transients can frequently lead to the pressure at the inlet to the fuel injector briefly exceeding the threshold pressure again and thus in so-called secondary injection briefly occurring, that is to say in the fuel injector injecting a small amount of fuel into the associated inlet duct or combustion chamber at some time after the principal or primary injection of fuel has terminated. This is generally thought to be highly undesirable and it is therefore usual to include a reverse flow damping valve, or a so-called snubber valve, in the supply line. This valve permits the substantially unthrottled flow of fuel towards the fuel injector but significantly damps or throttles any flow in the reverse direction. This valve substantialy damps pressure transients after the termination of the primary fuel injection and prevents the occurrence of secondary injection. The snubber valve is typically somewhat similar to a non-return valve in that it includes a movable valve member which is biased by a spring in a direction opposite to that of the fuel flow into sealing contact with a valve seat. However, the valve member has a restricted orifice formed in it. When fuel flows towards the fuel injector the valve body lifts away from the valve seat and the flow is substantially unthrottled. However, if fuel attempts to flow in the opposite direction the valve member is pressed into contact with the valve seat and can only flow through the restricted orifice which substantially throttles the flow and damps any pressure waves and thus suppresses secondary fuel injection.

It is also common to provide each outlet of the fuel injection pump with a so-called unloading valve which is biassed into the closed position but which is opened when a pressure pulse is applied to it by the pump to permit fuel to flow towards the associated fuel injector. As the pressure pulse dies away the unloading valve moves under the action of the biasing force into the closed position. This would normally result in the fuel in the supply line remaining under a pressure substantially equal to that at which the fuel injector operates to inject fuel. However, the movable valve member of the unloading valve is so shaped that as it moves into the closed position it returns a small volume of fuel from the supply line to the pump, thereby reducing the pressure in the supply line and further reducing the risk of secondary fuel injection occurring.

The present invention is based on the surprising recognition that secondary fuel injection, which was previously thought to be undesirable, can be very beneficial under certain circumstances because it results in an increase in the unburnt HC content of the exhaust gases and the increase is preferably selected to be just sufficient to ensure that the DeNOx catalyst can operate effectively.

Thus the reverse flow damping valve is selectively disabled after primary injection has occurred, e.g. under the control of an electronic control unit, such as the engine management system of the vehicle accommodating the engine, such that secondary injection occurs under certain engine operating conditions and the DeNOx catalyst is thus provided with the appropriate conditions to operate effectively.

Whilst the volume of the fuel injected during the secondary injection should be sufficient to increase the amount of unburnt HC in the exhaust gases to a level at which the catalyst may operate effectively, it is desirable that it is not significantly larger than this otherwise the secondary injection would unnecessarily impair the fuel consumption of the engine. It is therefore preferred that the volume of fuel injected during the secondary injection is between 2 and 10% of that injected during the primary injection.

The timing at which the secondary injection occurs should not be too soon after termination of the primary injection otherwise all the secondary fuel is simply burnt and does not lead to an increase in unburnt HC in the exhaust gases. Subject to this, however, the timing is not critical and may be during the expansion stroke or the exhaust stroke of a four stroke diesel engine. It is preferred that the secondary injection commences at between 30 and 90° crankshaft revolution after the top dead centre position of the associated piston.

The timing and volume of the secondary injection may be varied by varying the length of the fuel supply pipe between the snubber valve and the fuel injector.

The supply pipe is preferably between 200 and 600 mm long and preferably has an internal diameter of between 1 and 3 mm. It is also preferred that the fuel injection pump communicates with each supply pipe via an unloading valve of the type described above. The timing and volume of the secondary injection may also be varied by adjustment of the unloading valve, that is to say by adjusting the pressure at which the unloading valve closes and the volume of fuel which it returns to the fuel pump when it does so. The volume of fuel returned by the unloading valve to the fuel pump is preferably between 20 and 50 mm^3.

The reverse flow damping valve preferably comprises a movable valve member which defines a throttling orifice and is biased, e.g. by a spring in a direction opposite to the direction of flow of fuel towards the fuel injector into the closed position in contact with a valve seat. The flow of fuel towards the fuel injector results in the valve member lifting away from the valve seat and thus in the fuel flow being substantially unthrottled. However, once this flow of fuel terminates, the valve member normally moves under the biasing force into the closed position and if any fuel should attempt to flow in the reverse direction it is substantially throttled by the throttling orifice through which it is obliged to flow.

The disabling means may take various forms but in one embodiment of the invention it comprises an electromagnet which is e.g. selectively controlled by the engine management system and is arranged to hold the valve member of the reverse flow damping valve in the open position even when no fuel is flowing towards the fuel injector. When thus held open, the valve will not throttle any reverse flow of fuel and secondary injection by the fuel injector can take place.

In a further embodiment of the invention the disabling means comprises a mechanical member which is selectively movable into engagement with, or into the path of movement of, the valve member so as physically to prevent it from moving into the closed position.

In yet a further embodiment the disabling means comprises a bypass passage communicating with the fuel supply passage upstream and downstream of the reverse flow damping valve and a control valve in the bypass passage. The control valve is movable between a closed position, in which the bypass passage is closed and the reverse flow damping valve thus operates in the conventional manner, and an open position in which the reverse flow damping valve is effectively short-circuited and thus does not throttle the flow of fuel in either direction. The control valve may also be caused to adapt intermediate positions in which the reverse flow of fuel is throttled, but to a selected reduced extent, thereby influencing the timing and/or magnitude of the secondary fuel injection. A similar effect can also be achieved in the other embodiments by constructing the valve member and valve seat of the reverse flow damping valve so that they define a flow opening of progressively increasing area as the valve moves towards the fully open position, e.g. by making one of them of conical or of converging shape in the direction of the flow of fuel, and by arranging the disabling means to be capable of retaining the valve member in any desired intermediate position.

When used on a diesel engine of IDI type, the disabling means will typically be operated under most operating conditions, that is to say under all operating conditions other than at start-up of the engine and under high load conditions.

When the engine is started up the DeNOx ctalyst is cold and thus inoperative and there is therefore no point in deliberately further increasing the unburnt HC content of the exhaust gases. Under high engine load conditions the DeNOx catalyst tends to be too hot to operate effectively and there is therefore again no point in further increasing the unburnt HC content of the exhaust gases.

Further features and details of the invention will be apparent from the following description of certain specific embodiments which is given by way of example with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a view of part of a fuel injection system in accordance with the present invention;

Figure 2 is a schematic view on an enlarged scale of a modified construction of the reverse flow damping valve shown in Figure 1; and

Figures 3 and 4 are schematic views similar to Figure 2 of modified constructions of the reverse flow damping valve.

Referring firstly to Figures 1 and 2, the fuel injection system is suitable for a diesel engine of either DI or IDI type and includes a fuel injection pump (not shown) of rotary or other type known *per se* which has a number of outlet assemblies, of which only one, which is designated 4, is shown which corresponds to the number of the cylinders in the engine. Each such outlet assembly 4 is connected to an associated fuel injector (not shown) by a respective supply pipe (not shown) and the fuel injection system will be described in relation to only one fuel injector and associated outlet assembly since these are all identical. Situated in the outlet assembly 4 is a reverse flow damping valve or snubber valve comprising a stationary valve seat 6 and a movable valve member 8. Formed in the valve member 8 is a small throttling orifice 10. The valve member 8 is biased into the closed position in sealing contact with the seat 6 by a spring 12. Formed in the snubber valve housing 14 are two openings 16 into which respective portions of the iron core 18 of an electromagnet extend. The iron core 18 passes through the wall of the outlet assembly through respective high reluctance bushings 20. The electromagnet also includes an exciting winding 22. The portions of the iron core 18 which extend through the openings 16 are positioned to be engaged by the valve member 8, when in the open position, as shown in Figure 1 or to be closely adjacent to the valve member 8, when in the open position, as shown in Figure 2.

Also situated in the outlet assembly 4 of the fuel injection pump is an unloading valve comprising a barrel 2 and a piston 24, which is biased into the closed position by a spring 26. The unloading valve piston 24 is arranged to be opened by the pressure pulses applied to it by the fuel injection pump to permit fuel to flow from the pump into the outlet assembly and to be closed again under the action of the spring 26 as the pressure pulse dies away. The side surface of the unloading valve piston 24 is provided with an annular recess 28 which is situated within the barrel 2 when the valve is closed and outside the barrel 2 when the valve is opened and is arranged to trap fuel within it and thus to return fuel from within the outlet assembly to the barrel 2 as the unloading valve closes, thereby reducing the pressure prevailing in the outlet assembly 4 and the associated connecting pipe at those times when the fuel injector is not injecting fuel into the associated cylinder.

The operation of the fuel injection system if the disabling means constituted by the electromagnet 18, 22 is not actuated is conventional. Thus the unloading valve piston 24 opens periodically under the action of the pressure applied to it by the fuel injection pump to admit fuel into the outlet assembly 4. This fuel flows towards the fuel injector and causes the snubber valve member 8 to lift off its seat whereby the flow of fuel towards the injector is effectively unthrottled. As the pressure in the outlet assembly 4 and the connecting pipe rises above a threshold value injection of fuel into the associated cylinder by the fuel injector commences. This fuel injection ceases once the pressure falls below the threshold value again and the unloading valve piston 24 is then closed by the spring 26. As it does so, a certain amount of fuel is returned to the outlet 2 within the recess 28 and this results in a reduction in the pressure in the supply pipe 4. At substantially the same time the snubber valve member 8 is moved by the spring 12 into the closed position. Any pressure waves caused by the termination of the primary injection of fuel are damped by the throttling orifice 10 to the effect that the pressure fluctuations that occur are not sufficient to result in secondary injection of fuel occurring at some time after the primary injection has ceased. The fuel injection system will typically be operated in this manner when fitted to an IDI diesel engine when the engine is started and for a brief period thereafter and when the engine is operating under high load conditions.

However, when an IDI diesel engine fitted with this fuel injection system is operated under e.g. low load conditions it is desirable for the unburnt HC content of the exhaust gases to be increased to a level at which the DeNOx catalyst in the exhaust system can operate with maximum efficiency. This is achieved by applying a voltage to the exciting coil 22 of the electromagnet, under the control of the engine management system, which results in the snubber valve member 8 being retained in the open position on the next occasion that it opens. Accordingly, when primary injection of fuel by the fuel injector is subsequently terminated, pressure waves and transients which occur in the fuel injection system are not damped by the snubber valve. The system is tuned, e.g. by adjusting the size of the annular recess 28 in the unloading valve piston 24 and the length and internal diameter of the connecting pipe between the outlet assembly 4 and the fuel injector to ensure that these pressure transients result in a brief secondary injection of fuel occurring. This secondary injection occurs at a time and in a volume which is sufficient to result in the unburnt HC content of the exhaust gases being substantially at that level which is necessary for the DeNOx catalyst to operate with maximum efficiency.

If the engine should subsequently enter a high load condition in which, as explained above, there is no benefit from increasing the unburnt HC content of the exhaust gases, this fact is sensed by the engine management system which de-energises the coil 22 and the snubber valve is then permitted to operate in the conventional manner until the coil 22 is re-energised.

The modified embodiment of the snubber valve shown in Figure 3 is very similar to that shown in Figure 2 but in this case the electromagnet is replaced by a pivotal stop member 30 which may be moved by means of an actuator (not shown) under the control of the engine management system between the position shown in Figure 3, in which it physically prevents the snubber valve member 8 returning to the closed position, and an inoperative position in which the snubber valve member is permitted to open and close in the conventional manner.

The further modified embodiment of the snubber valve shown in Figure 4 is again similar to that shown in Figure 2 but in this case there are no means arranged selectively to prevent the snubber valve member 8 from closing and it therefore always opens and closes in the conventional manner. However, the snubber valve is bypassed by a bypass passage 32 which is provided with a valve 34, which is shown in this case as a gate valve, which is movable between an open and a closed position by an actuator (not shown) under the control of the engine management system. As will be clear, the bypass passage 32 and valve 34 constitute the disabling means in this embodiment and if it is desired to suppress secondary fuel injection the valve 34 is closed and the snubber valve operates in the conventional manner. If however, secondary fuel injection is desired, the valve 34 is opened and whilst the snubber valve still opens and closes in the conventional manner, backflow of fuel is not throttled because the open bypass passage constitutes an unconstricted flow path for such flow.

Claims

1. A fuel injection system for a diesel engine with a DeNOx catalyst comprising a fuel injection pump arranged to produce periodic pressure pulses and at least one fuel injector connected to the fuel pump by a respective outlet assembly (4) and supply line, the outlet assembly (4) including a reverse flow damping valve (6, 8) and an unloading valve (2,24), characterised by disabling means (18, 22; 30; 32, 34) arranged selectively to reduce or eliminate the reverse flow damping function of the reverse flow damping valve (6, 8).

2. A system as claimed in Claim 1 in which the reverse flow damping valve comprises a movable valve member (8) in which a throttling orifice (10) is formed and which is biassed into the closed position in contact with a valve seat (6).

3. A system as claimed in Claim 2 in which the disabling means comprises an electromagnet (18, 22) arranged selectively to hold the valve member (8) in the open position.

4. A system as claimed in Claim 2 in which the disabling means comprises a mechanical member (30) which is selectively movable into a position in which it physically prevents the valve member (8) moving into the closed position.

5. A system as claimed in Claim 2 in which the disabling means comprises a bypass passage (32) communicating with the fuel flow passage in the outlet assembly (2) upstream and downstream of the reverse flow damping valve (6, 8) and a control valve (34) arranged selectively to close the bypass passage (32).

6. A diesel engine including a DeNOx catalyst and a fuel injection system as claimed in any one of the preceding claims.

7. A diesel engine as claimed in Claim 6 which is of Indirect Injection type.

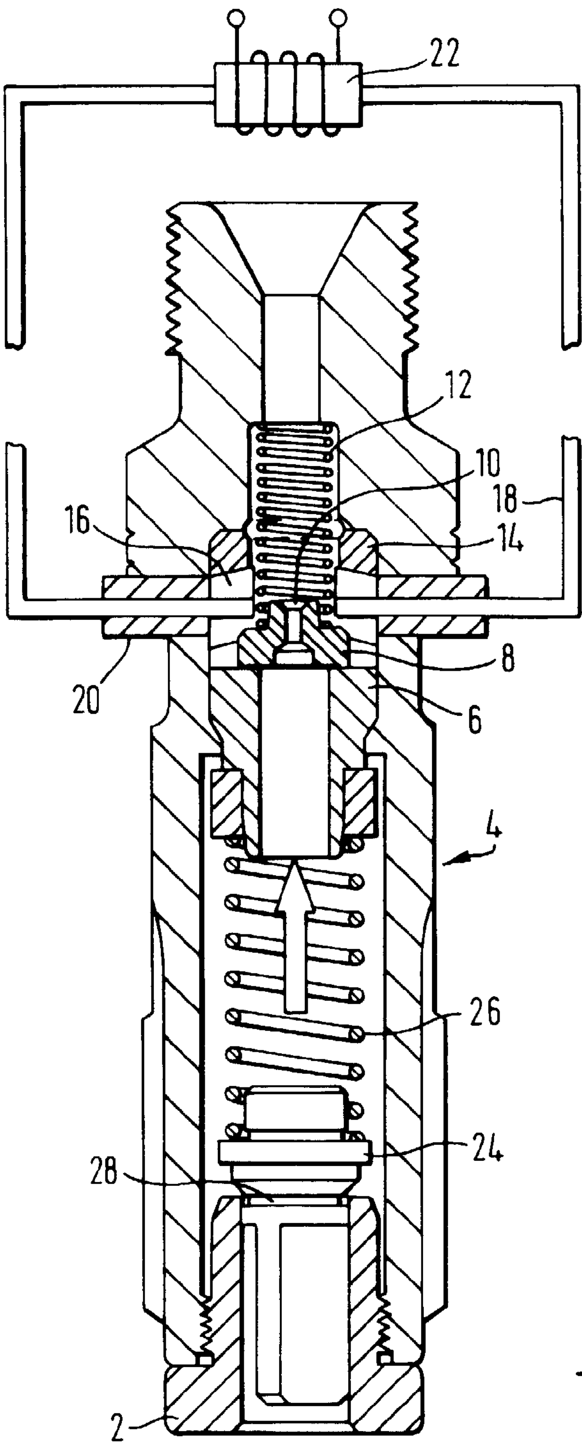

FIG. 1

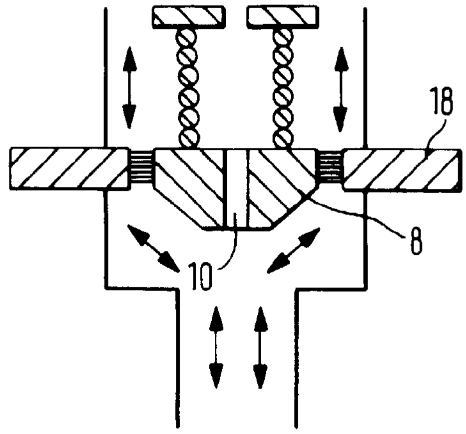

FIG. 2

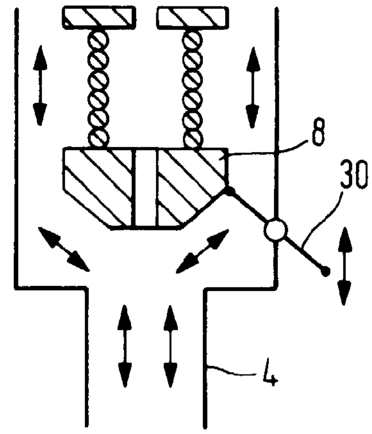

FIG. 3

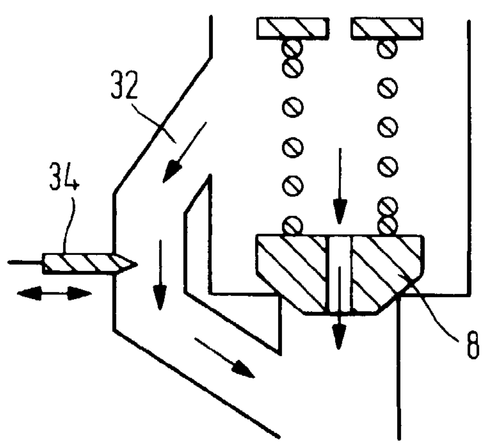

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 4890

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	PATENT ABSTRACTS OF JAPAN vol. 010, no. 353 (M-539), 28 November 1986 & JP 61 152961 A (HINO MOTORS LTD), 11 July 1986 * abstract *	1-3 5	F02M59/46
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 604 (M-1506), 8 November 1993 & JP 05 180117 A (NIPPONDENSO CO LTD), 20 July 1993 * abstract *	5	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 September 1998	Sideris, M

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