surface of the shut off valve member defines a second effective surface area, whereby the associated second surface of the shut off valve member is engageable with a shut off valve seating to control fuel flow through the fuel supply passage.

[0053] Conveniently, the hydraulic force acting on the first effective surface area opposes the hydraulic force acting on the second effective surface area.

[0054] In one preferred embodiment, the associated second surface defines a seating surface of substantially conical form for engagement with the shut off valve seating.

[0055] Preferably, for example, the associated first surface is defined by a first end region of the shut off valve member and an opposite end region of the shut off valve member is exposed to relatively low fuel pressure.

[0056] In this embodiment the associated second surface may be defined by an intermediate region of the shut off valve member.

[0057] In a further preferred embodiment the shut off valve member is shaped such that any force imbalance on the shut off valve member is substantially the same when the shut off valve member is in both its open and closed operating positions.

[0058] It has been found that a shut off valve of this configuration has improved force balancing, as any out of balance forces that act on the shut off valve member are substantially the same when the shut off valve member is in both the open and closed operating positions. This characteristic is particularly beneficial for achieving a pilot injection of fuel or any other injection of relatively small fuel volume.

[0059] Preferably, the shut off valve member is slideable within a bore in a valve housing and is shaped to define, together with the bore, an annular chamber through which high pressure fuel flows when the shut off valve member is in the open operating position.

[0060] The shut off valve seating may be substantially flat and is defined by a step in a housing bore within which the shut off valve member moves. Alternatively the shut off valve seating or may be of frusto-conical form.

[0061] In an alternative embodiment of the shut off valve, the associated first surface is defined by a first end of the shut off valve member and the associated second surface is defined by an opposite end of the shut off valve member. In this case the associated second surface may be engageable with a shut off valve seating defined by an end face of a housing part.

[0062] The shut off valve member may be substantially pressure balanced, and preferably may then include spring means, in the form of a spring arrangement (for example a compression spring), for urging the shut off valve member towards its closed position.

[0063] However, the shut off valve need not be pressure balanced, in which case the effective surface area of the first associated surface may be greater than the effective surface area of the second associated surface.

[0064] Preferably, the control valve is operable between a first position in which the shut off valve control chamber communicates with fuel at an injectable pressure and a second position in which the shut off valve control chamber communicates with fuel at a relatively low pressure. If the shut-off valve is implemented in a fuel injection system in accordance with the first aspect of the invention, the injectable pressure may be the first, moderate pressure level, or may be the second higher pressure level. It will be appreciated, however, that the shut-off valve of this second aspect of the invention may also be implemented in a fuel injection system other than of the type described herein.

[0065] In an alternative embodiment, the control valve is operable between a first position in which the shut off valve control chamber communicates with fuel at a pressure level that is different to the injectable pressure level and a second position in which the shut off valve control chamber communicates with fuel at a relatively low pressure.

[0066] According to a third aspect of the invention, a fuel injector for use in an internal combustion engine includes an injection nozzle having a valve needle and a valve needle seating, said valve needle being movable between an open position in which it is lifted away from the valve needle seating and a closed position in which is engaged with the valve needle seating, a fuel supply passage and a shut off control valve that is actuable between an open position in which high pressure fuel flows through the fuel supply passage to the injection nozzle and a closed position in which high pressure fuel cannot flow through the fuel supply passage to the injection nozzle, and whereby the shut off valve is actuable between its open and closed position with the valve needle is in its open position so as to provide a pulsed injection of fuel to the injector.

[0067] The fuel injector incorporating the shut off valve permits a pulsed injection of fuel to be achieved, without the requirement to re-seat the valve needle between the injected pulses. This enables a rapid pulsing of fuel injection, and is particular useful for achieving a pilot injection of fuel followed by a main injection of fuel.

[0068] It will be appreciated that any one or more of the preferred and/or optional features described previously for the shut off valve of the second aspect of the invention may be included as preferred or optional features of the fuel injector of the third aspect of the invention also. Likewise, the preferred and/or optional features of the second or third aspects of the invention may be incorporated as preferred and/or optional features in the fuel injection system of the first aspect of the invention also.

BRIEF DESCRIPTION OF THE DRAWINGS

[0069] Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0070] **FIG. 1** is a schematic diagram illustrating a known Electronic Unit Injector system,

[0071] **FIG. 2** is a schematic diagram illustrating a known common rail fuel injection system,

[0072] **FIG. 3** is a schematic diagram of a first embodiment of a fuel injection system in accordance with one aspect of the present invention, and in which the system is in a first operating state,