Exhaust Gas Recirculation is an efficient method for NOx control in diesel engines. The constituents of exhaust gases are carbon dioxide, nitrogen and water vapor. When part of this exhaust gas is recirculated into the cylinder it acts as diluents to the combusting mixture. The specific heat of the EGR is much superior to fresh air, therefore EGR increases the specific heat capacity of the intake charge thereby decreasing the temperature rise for a similar heat release in the combustion chamber. Recirculated exhaust gas replace fresh air that entering the combustion chamber by carbon dioxide and water vapour present in engine exhaust. As a result of this air replacement, the quantity of oxygen in the intake is decreased. Reduction in oxygen level required for combustion lowers the effective air fuel ratio which affects exhaust emissions considerably. The mixing of exhaust gas with intake air increases the specific heat of combustible mixture, which results in the reduction of flame temperature. This combination of low oxygen in the intake and reduced flame temperature reduces the NOx formation reaction rate. The EGR percentages defined as,

\[
\% EGR = \frac{\text{Volume of EGR}}{\text{Total intake charge into the Cylinder}} \times 100 \quad (6.1)
\]

Another method of determining the extent of EGR is by the use of CO₂ concentration.
Three most popular explanations for the effect of EGR on NOx reduction are (i) increased ignition delay, (ii) high heat capacity and (iii) concentration of the intake charge by means of inert gases. The heat capacity hypothesis states that “the addition of the inert exhaust gas in the intake increases the specific heat capacity of the non-reacting substance available for combustion”. According to the dilution theory, “the effect of EGR on NOx is caused by increase in inert gas quantity in the mixture that decreases the adiabatic flame temperature”. It is not easy to implement EGR at higher loads due to drop in diffusion combustion which results in an excess smoke and particulate emissions. But at low loads, unburnt hydrocarbons restricted in the EGR reburn, that result in lower unburnt fuel in the exhaust. Apart from this, hot EGR would raise up the intake temperature, thereby influencing combustion and exhaust emissions. Application of EGR in diesel engines has limitations like increased soot emission and introduction of particulate matter into the engine cylinders. When the engine mechanism come in make contact with high velocity soot particulates, surface scratch may occur. Sulphuric acid and condensed water vapor in EGR also cause corrosion. Ignition delay, upsurged heat capability and strength of intake charge with inert gases are the three popular explanations for the effect of EGR on NOx decrease. EGR causes an upsurge in ignition delay which is comparable as hold up the
injection timing. The heat capacity hypothesis states that “addition of exhaust gas into the intake upsurge the heat capacity”, which lower the maximum combustion temperature. According to the dilution theory, when higher quantity of inert gas is the mixed, the result is lower the adiabatic flame temperature which reduces NOx formation inside the chamber.

Instead of using exhaust gas after treatment systems to comply emission norms, it is possible to reduce the emissions during the combustion stage itself. The raw emissions are reduced and thereby after treatment is not required. The most common practice in recent days is to use EGR to reduce the formation of NOx emissions. A part of the exhaust gases is recirculated into the combustion chambers. This can be achieved either internally with the proper valve timing, or externally with some kind of piping, Figure 8 shows this schematically. The exhaust gas acts as an inert gas in the combustion chamber, it does not participate in the combustion reaction. This leads to a reduction of the combustion temperature by different effects. The fuel molecules need more time to find a oxygen molecule to react with, as there are inert molecules around. This slows down the combustion speed and thus reduces the peak combustion temperature, as the same amount of energy is released over a longer period of time. The energy is also used to heat up a larger gas portion than it would without EGR. As the air is diluted with exhaust gas, the mass of a gas portion containing the needed amount of oxygen gets bigger.
Another effect is the change in heat capacity. Exhaust gas has a higher specific heat capacity than air, due to the CO₂ molecule’s higher degree of freedom. So for the same amount of combustion energy a gas mass containing EGR will get a lower temperature than pure air. Several difficulties have to be taken into account when EGR is used. When the exhaust gas is taken out of the exhaust system upstream of the turbocharger, the energy of this gas is lost for the turbocharger. This decreases the useable exhaust energy for compressing the intake air and thus the amount of air that gets into the cylinder. This amount of air is directly coupled to the amount of EGR that the engine can run, because the limiting factor is the air/fuel ratio in the cylinder.

Another problematic area is the control of emissions during transients. As it is desirable to get a maximum acceleration, the EGR is usually shut off when the load is increased, to provide the maximum amount of available air.

6.1 Classification of EGR systems:

6.1.1 Classification Based on temperature:

- **Hot EGR**: Exhaust gas is recirculated without being cooled which results an upsurged intake charge temperature.

- **Fully Cooled EGR**: Exhaust gas is completely cooled before mixing with fresh intake air using water cooled heat exchanger.
Partly Cooled EGR: The temperature of the exhaust gas is just kept above its dew point temperature to keep away from water condensation.

6.2 Classification Based on Configuration

Short Route System (SR): These systems be different primarily in the method used to set up a positive pressure dissimilarity across the EGR circuit.

6.3 Classification Based on Pressure:

Low pressure route system: The opening for EGR is providing from downstream of the turbine to the upstream side of the compressor. It is originate that by using the low pressure route system, EGR is possible up to a high load region with considerable drop in NOx.

High pressure route system: The EGR is passed from the upstream of the turbine to downstream of compressor. In this method, although EGR is potential in high load regions, the excess air ratio reduce and fuel consumption upsurges remarkably.