Analysis of Use of Low Purity Gas in Engines

Safety implications

Running gas engines on gas supplied at low purity is hazardous for the following reasons.

(a) Engine

(i) If the engine is run at a “lean” fuel/air mixture there is an increased risk of detonation in the combustion chambers, burning of exhaust valves and premature failure of moving parts.

(ii) Any flame escaping past inlet valves into the inlet manifold could ignite gas in the compressor, and then cause an ignition in the gas inlet pipe range. If flame arrestors are fitted and maintained at 100% reliability, the mine gas pipeline may not explode. If, however, any flame arrestor fails, the entire gas pipeline system, possibly including the underground system, could explode.

(b) Surface gas pipeline

(i) Any leakage in this part of the pipeline is OUTWARDS. Any stray igniting source (illegal smoking, lightning, vehicle exhausts, electrical faults, welding sparks, coke braziers in winter, etc) could cause the entire pipe system to explode, possibly including the underground pipeline.

(c) Shaft pipe range

(i) Any leakage in this part of the pipeline is INWARDS. Any igniting source (impacts with shaft vehicles or ropes, falling objects, electrical faults etc) could cause the entire pipe system to explode, including the underground pipeline.

(d) Underground pipe system

(i) Any leakage in this part of the pipeline is INWARDS. Any igniting source (impacts with vehicles or loads, falling objects, electrical faults, shot firing etc) could cause the entire pipe system to explode.

The fundamental concept here is that there is no ***intrinsic*** safety, as would be afforded by maintaining a high purity of gas in the pipe ranges. Lacking this intrinsic safety feature, the safety of the entire system rests on there being no accidents that breach the pipeline, rather than ensuring that such breaches expose non-explosive gas. In the rest of the world, accidents to pipe ranges do not result in explosions because the gas is at too high a purity to burn, except at the fringe where it mixes with air. This means that any gas ignitions remain localised, and can be eliminated by hand-held extinguishers.

Any ignition of low purity gas in a pipe range is immediately catastrophic because the flame front can accelerate outwards in both directions in the pipe, creating explosive forces, and putting the entire mine in jeopardy.

Financial and practical implications

By failing to maintain high gas concentrations in the degasification systems and in the pipelines, mine operators cannot take advantage of one of the most important features of mine gas drainage, i.e. the transport of small volumes of high purity gas, in optimally-sized reticulation systems.

A mine gas drainage system is designed to be the opposite of the ventilation system. Whereas the ventilation system circulates huge volumes of air to dilute gas to very low purities, using expensive, large cross-sectional area airways, the mine gas drainage system uses small diameter pipes to transport high purity gas.

As an illustration, take the following example.

A longwall producing a million tonnes of coal per year uses a methane drainage system to remove 800 litres per second of pure methane equivalent from seams adjacent to the goaf.

The pipe system has a length of 5000m, the suction at the outer end is 40 kPa, and the suction at the longwall is 10 kPa.

If the degasification system transports gas at 75% purity, as it is designed to do, the pipe diameter must be a reasonable 320mm, but if the purity is allowed to fall to 10%, *the pipe must be 718mm in diameter,(not practical in normal mining conditions.)*

In addition, the number and capacity of surface exhauster pumps is also much higher. It should be noted that in our example, at the lower purity, the overall flow must increase from 1066 l/s to 8000 l/s.

In this case (assuming larger pipes have been installed) the power required at the pumps will increase by 7.5 times.

Another way of looking at the effect of dilution is to note that if dilution of the gas results in a doubling of the gas/air flow (assuming the same diameter pipes), then the pressure lost in the pipes increases by 4 times (pressure $\propto$ flow^2), and the power required increases by 8 times (power $\propto$ flow^3)

Comments on research operating engines on low concentration methane

The research being undertaken in some countries to run gas engines at low gas purities could be seen to be driven by a failure to conduct mine degasification correctly.

It should be remembered that gas exists in the strata at 100% purity ***in every case***. The gas might be a mixture of gases, but it does not include air.

Consequently, if the gas in a degasification system pipeline is less than 100% pure, it has been diluted by allowing the in-leakage of air. With few exceptions, the world's coal producing nations make every effort to maintain their degasification systems gas purity at a high level, both for safety (usually enshrined in law), and for practical reasons.

There is no geological, stratigraphic or petrographic reason for gas emissions in any mine to be transported in the explosive range. Investment in degasification systems to improve efficiency, dramatically improve safety and create a valuable energy resource can easily be justified. Conversely, development of intrinsically unsafe gas utilisation systems to offset underperforming degasification systems is far harder to justify.

The following diagrams illustrate the additional hazards when operating a degasification system at lower purity.

It should be noted that underground pipe systems are vulnerable to damage, even in the most regulated mines. The principal potential source of such damage is mining equipment, including mineral conveyors, rope haulage systems, locomotives and their loads, and blasting activities. There is also the potential for damage from strata movement, and roof collapse.

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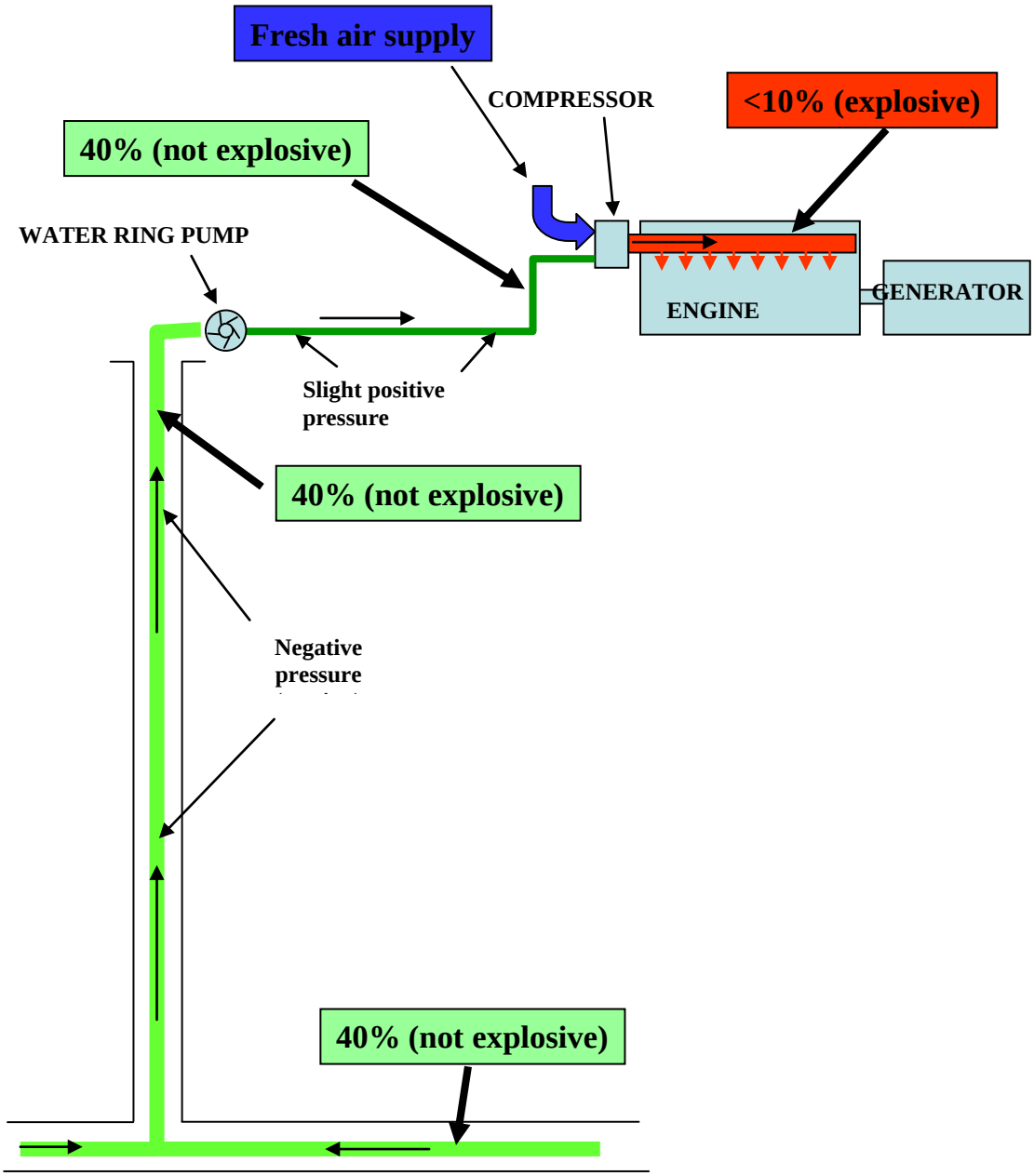
STANDARD INTERNATIONAL SYSTEM



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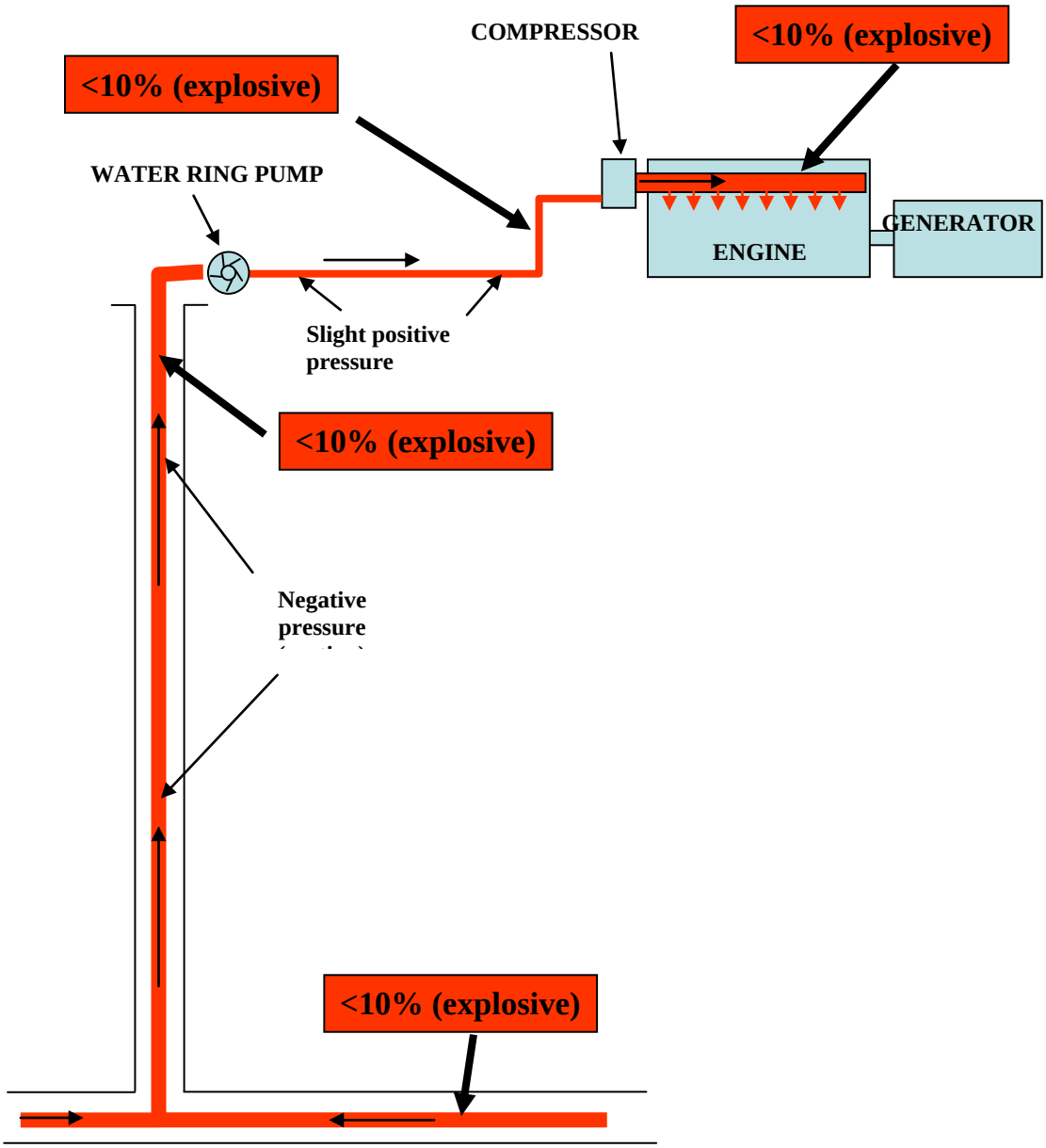
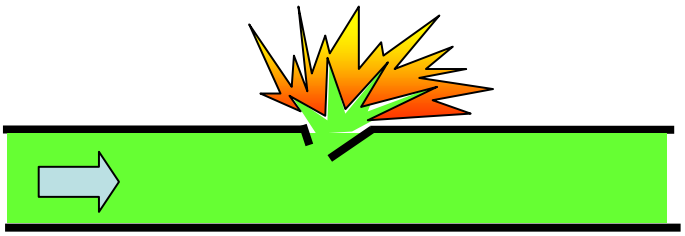
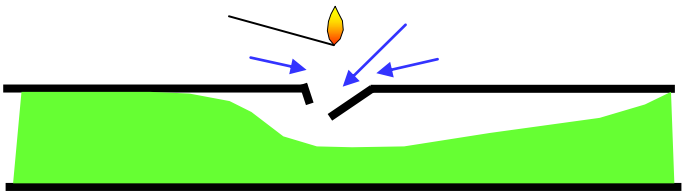
PROPOSED LOW CONCENTRATION GAS SYSTEM

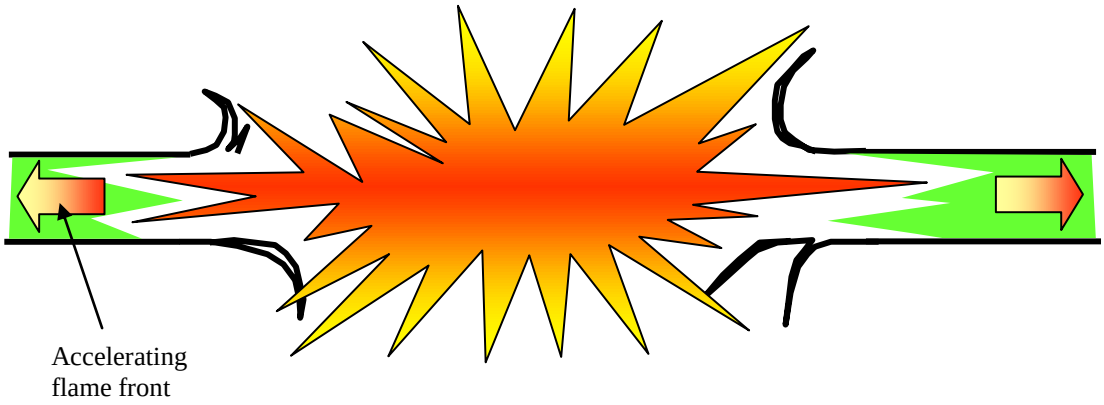




Positive pressure line - 40% purity
Gas burns on exit, no explosion



Negative pressure line - 40% purity
Flame cannot propagate, no explosion



Positive ***or*** negative pressure line
<15% purity
Explosion in both directions,