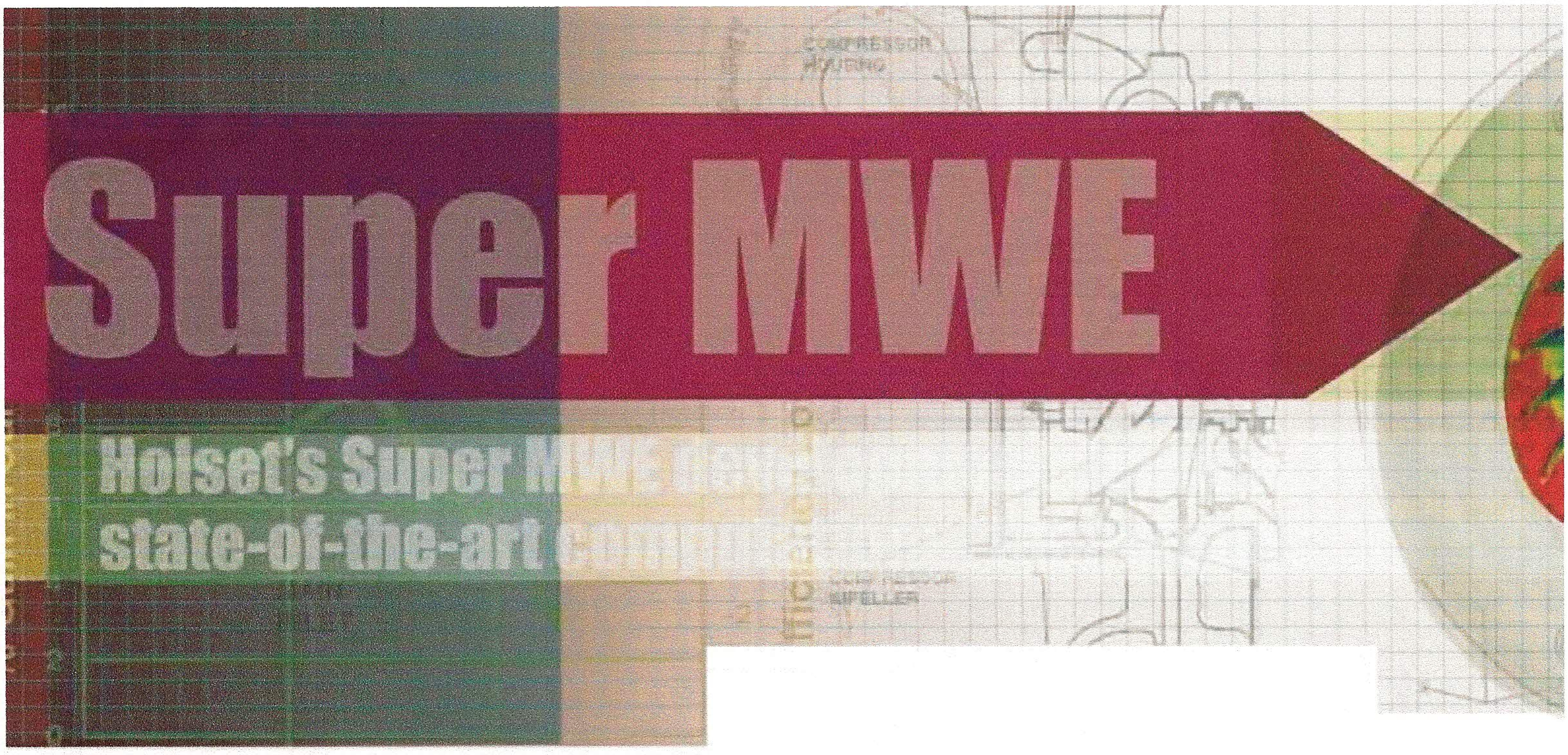


# Super MWE

**At a time of ever tougher legislative demands on the diesel engine, centred chiefly on exhaust emissions, one of the key challenges for turbocharger designers has been to improve the centrifugal compressor's flow range.**

Holset has in recent years explored a number of technologies targeting such improvements. Among the most promising areas of development over the years has been map width enhancement (MWE), which has progressed through several stages to Super MWE™ on which Holset has detailed design patent applications and trademark applications.

For a diesel engine, the air flow and pressure ratio requirements can be translated onto the flow map of a centrifugal compressor as a series of operating lines for various engine speeds (fig 1). The low engine speed lines are close to and almost parallel to the surge line of the compressor. Increasing the speed range of the engine increases the requirement for a correspondingly wider compressor map. Dynamic conditions during gear changing or changes in fuelling rate also require a generous air-flow margin around the engine operating lines.

Surge is a condition of instability created at any given speed as the flow rate through the compressor is reduced. Surge is a 'system' dependent event. The volume and length of a system's pipes affect the onset of surge. Large fluctuations in pressure and mass flow occur when the compressor is in surge. This unstable running condition can lead to eventual failure of the turbocharger.

Clearly it is desirable during normal engine operation to maintain a 'safe' margin away from surge. This is sometimes referred to as the 'surge margin'. If the surge flow can be reduced (thereby increasing the surge margin), the additional flow range can be harnessed to enhance the torque curve and hence the driveability of the engine. In some cases it can also help utilisation of more effective emissions reducing technology.

Use of a MWE slot (fig 2), also known as a 'shroud bleed', is an established technique for improving the surge margin of the centrifugal compressor. It helps improve the surge margin by recirculating the reverse flow to the front of the impeller when surge is imminent. The MWE slot also helps improve the choke side of the map by allowing additional air into the compressor past the throat area of the impeller (fig 3).

In the most recently developed Super MWE compressor (fig 4), the MWE inlet pipe length is optimised to provide additional flow range under surge conditions. We have shown that it is possible to get surge margin improvements of up to 15% by optimising the compressor inlet. Fig 5 shows the relative improvements achieved through the application of MWE and of Super MWE compared with a simple non-MWE compressor.

Holset's Super MWE development demonstrates just how Holset has applied state-of-the-art computational techniques in analysis-led design methodology. Computational fluid dynamics (CFD) models of the MWE pipe length extensions were generated and run in the computer to simulate real operating conditions under near-surge conditions. The CFD model represented the entire compressor stage (i.e. from impeller inlet to compressor housing outlet). Fig 6 shows a cross-section of the computational mesh used and fig 7 shows a sample of the results, again for a near-surge condition, at maximum impeller speed.

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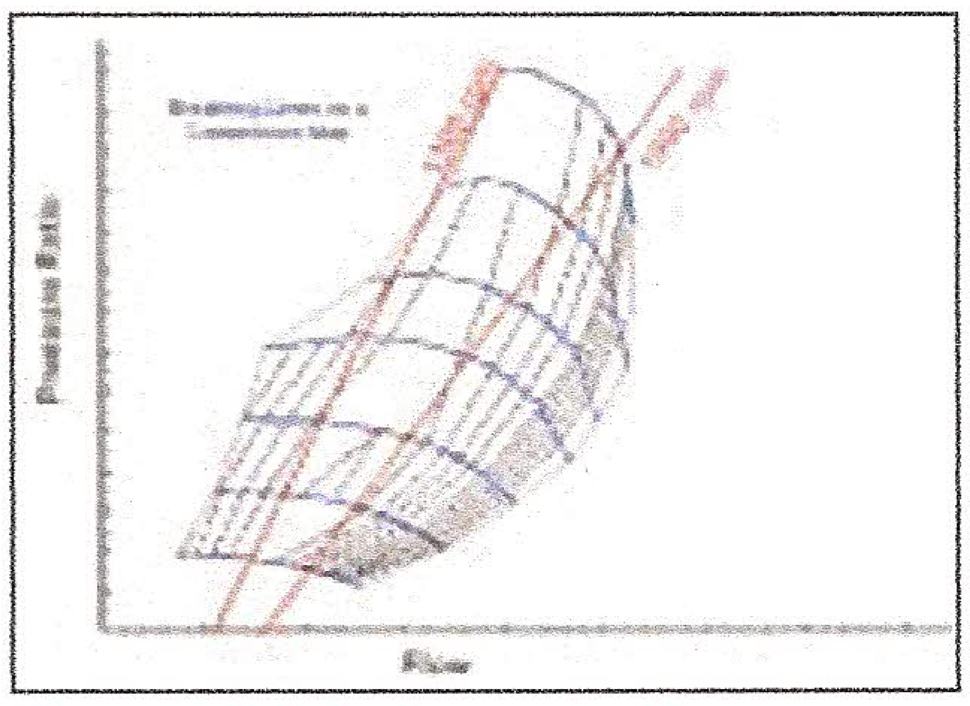


Fig 1 – Typical Engine running lines superimposed on compressor map

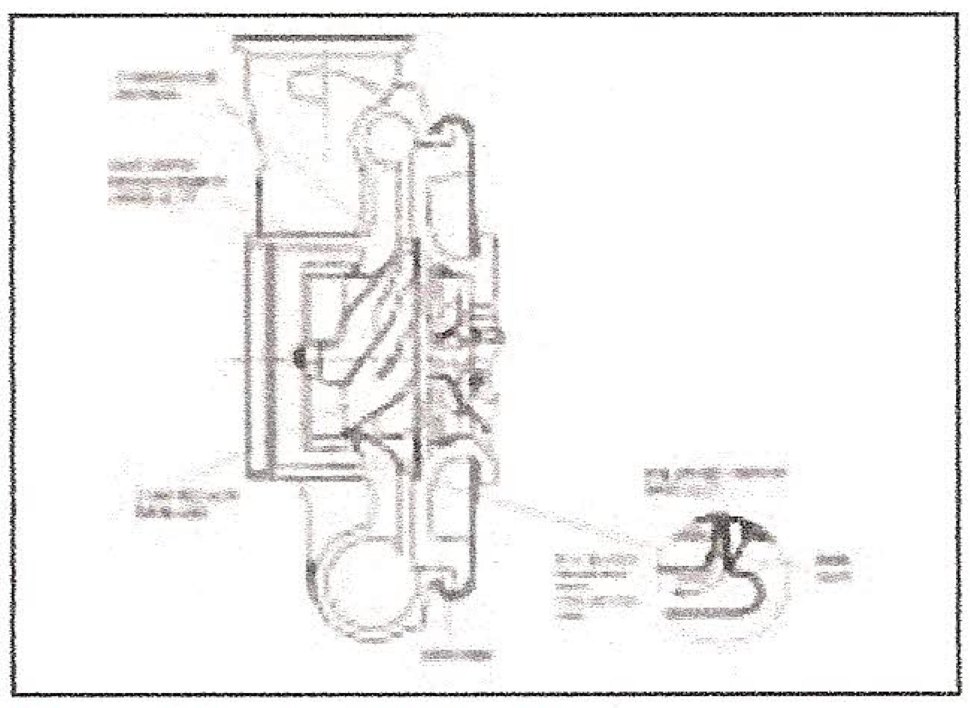


Fig 2 – Standard MWE slot

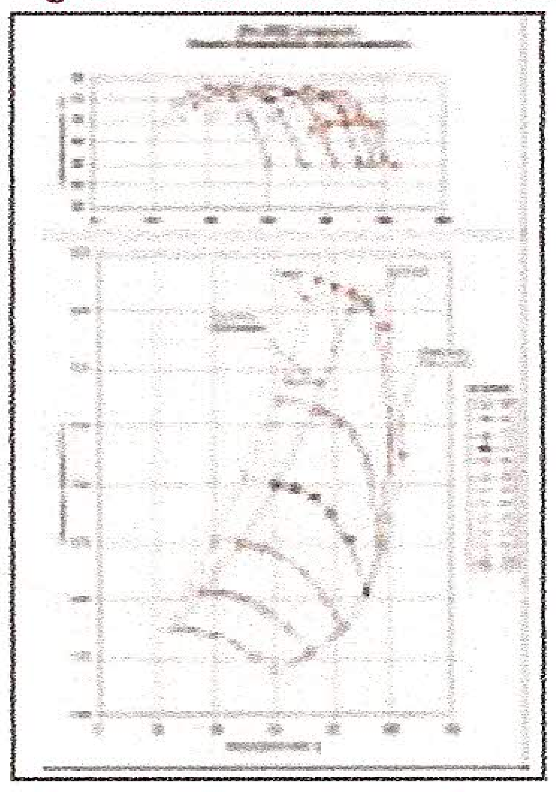
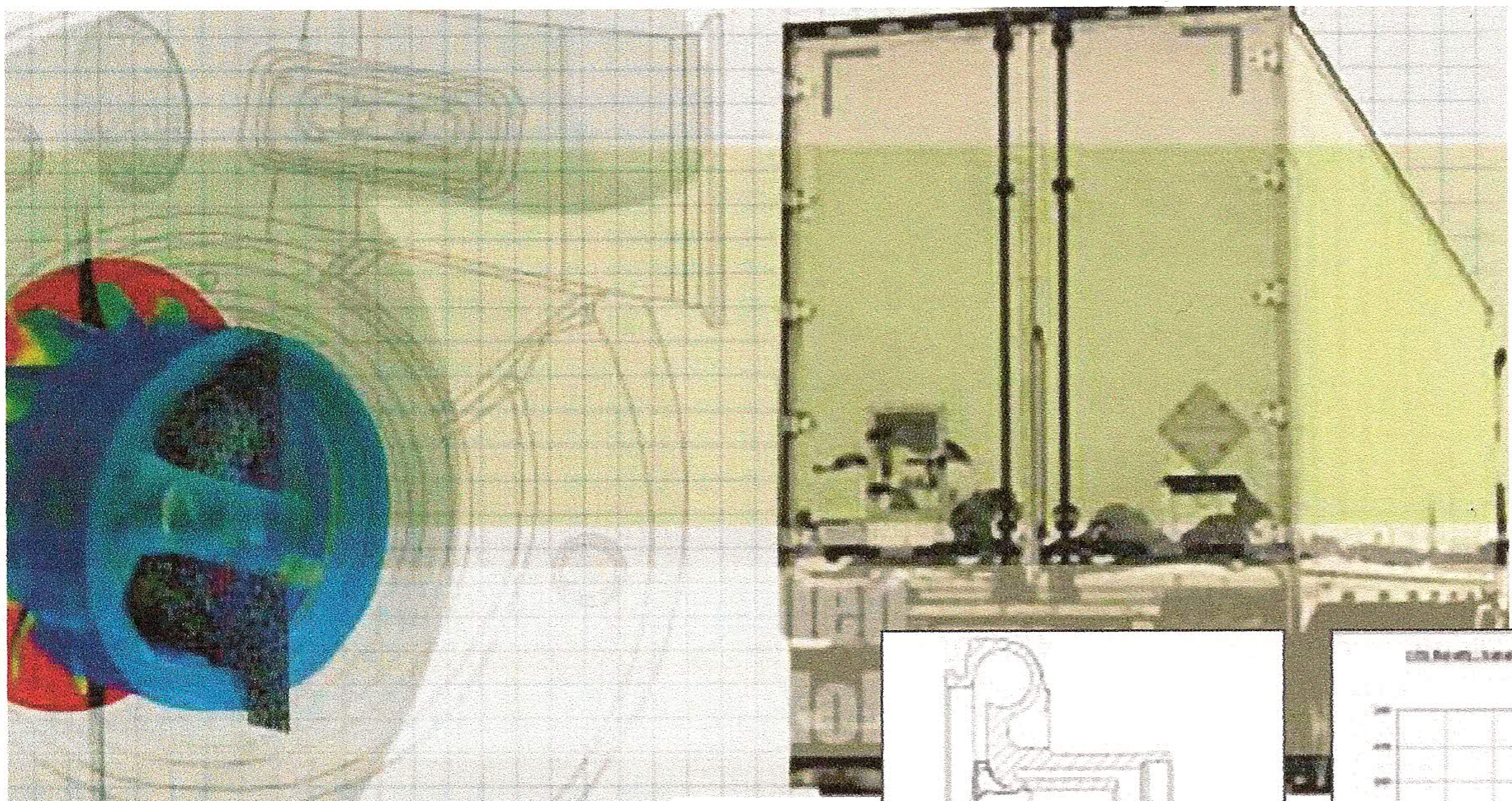


Fig 3 – Effect of MWE on compressor performance



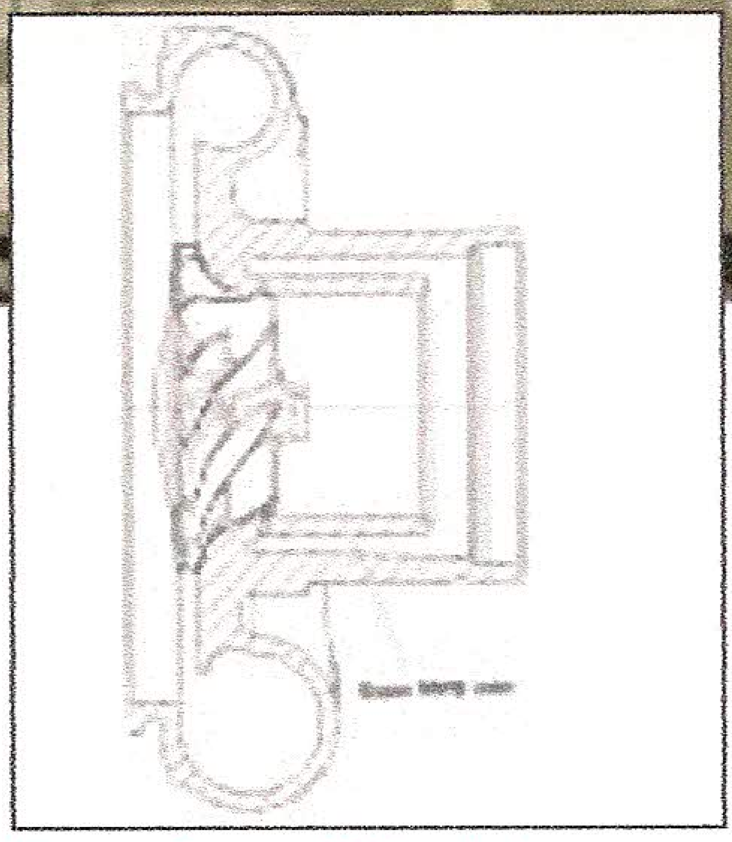


Fig 4 – Super MWE inlet

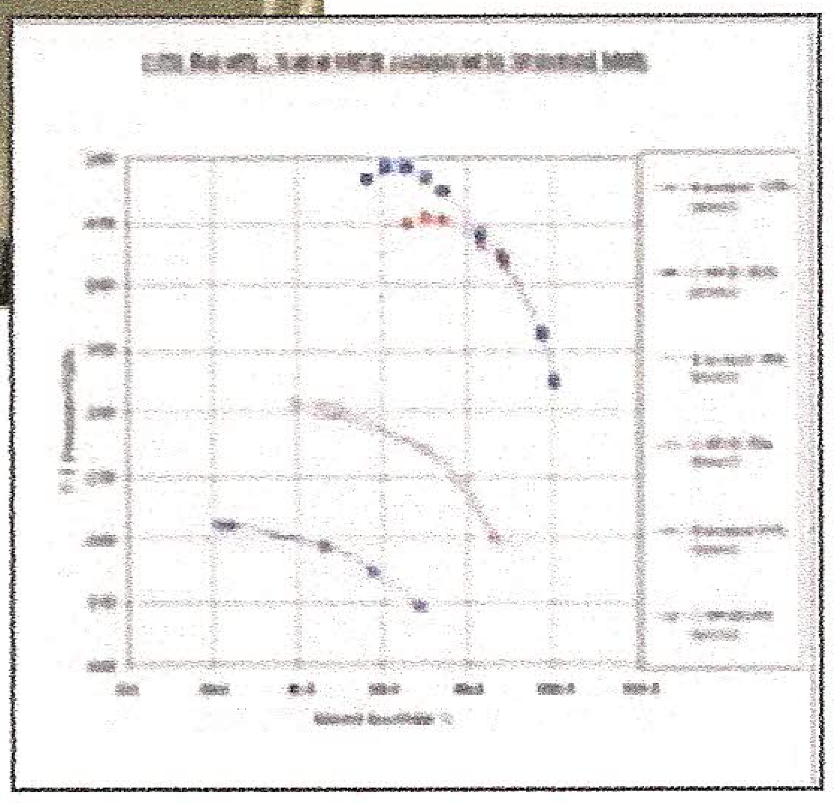


Fig 8 – CFD predicted performance map for Super MWE

All three cases shown on fig 7 were run to the same mass flow rate. In the standard MWE case, the reverse flow coming out of the MWE slot is remixing with the main inlet flow to cause a disturbance to this flow. Evidence for this is apparent in the Mach number contours at the tip of the MWE inlet pipe. The longer MWE inlet pipe results shows that the disturbance to the flow (due to MWE flow) occurs further upstream so the impeller inlet flow is more uniform. Our CFD results confirm that Super MWE is particularly effective under near surge conditions because it helps move the recirculating MWE flow further upstream from the impeller inlet.

Fig 8 shows (presented in performance map format) the CFD stage results for the standard and the longest MWE inlet pipe seen in fig 7. The CFD prediction shows a significant level of surge-margin improvement.

Testing of fabricated compressor housings with varying MWE inlet pipe lengths (fig 9) has verified our CFD data. Test results (summarised in fig 10) show that by increasing the MWE inlet pipe length, surge-margin improvements of up to 15% are achievable. However, the benefits do level off with increasing length. The longer pipes bring a drop in efficiency of around 2%. A compromise therefore needs to be made between the level of surge-margin improvement, package size increase and loss of efficiency.

The map over-plot shown in fig 11 demonstrates however that a moderate increase in inlet pipe length (as in fig 4) can yield an up to 12% surge-margin improvement with only about a 1% drop in efficiency.

With such an increase in map width, engine manufacturers have the option to run at conditions not previously possible, without the need to resort to complicated variable geometry compressor (VGC) technology.

Engine manufacturers will soon be able to take advantage of this technology as Holset are in the position to implement Super MWE into production.

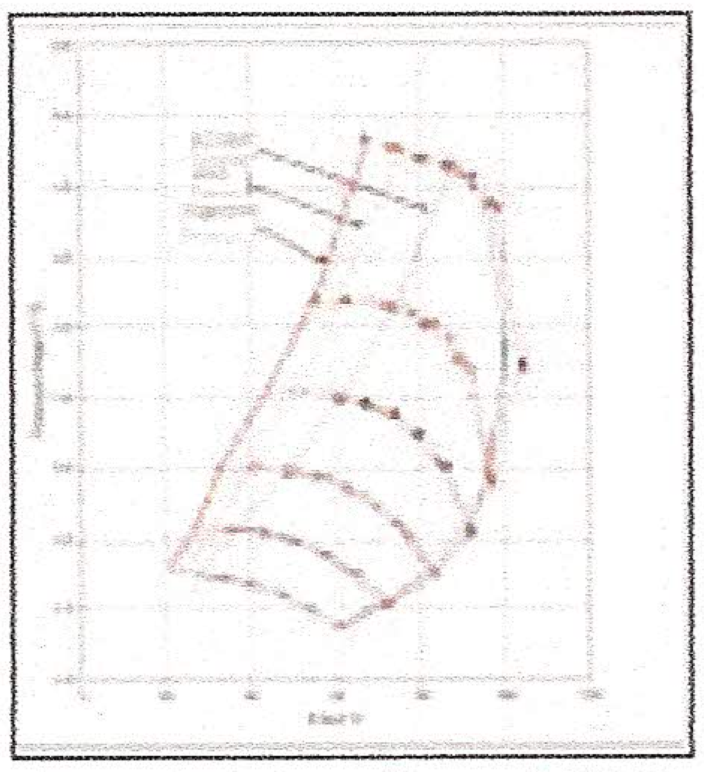


Fig 5 – Relative effects of MWE & Super MWE on compressor performance

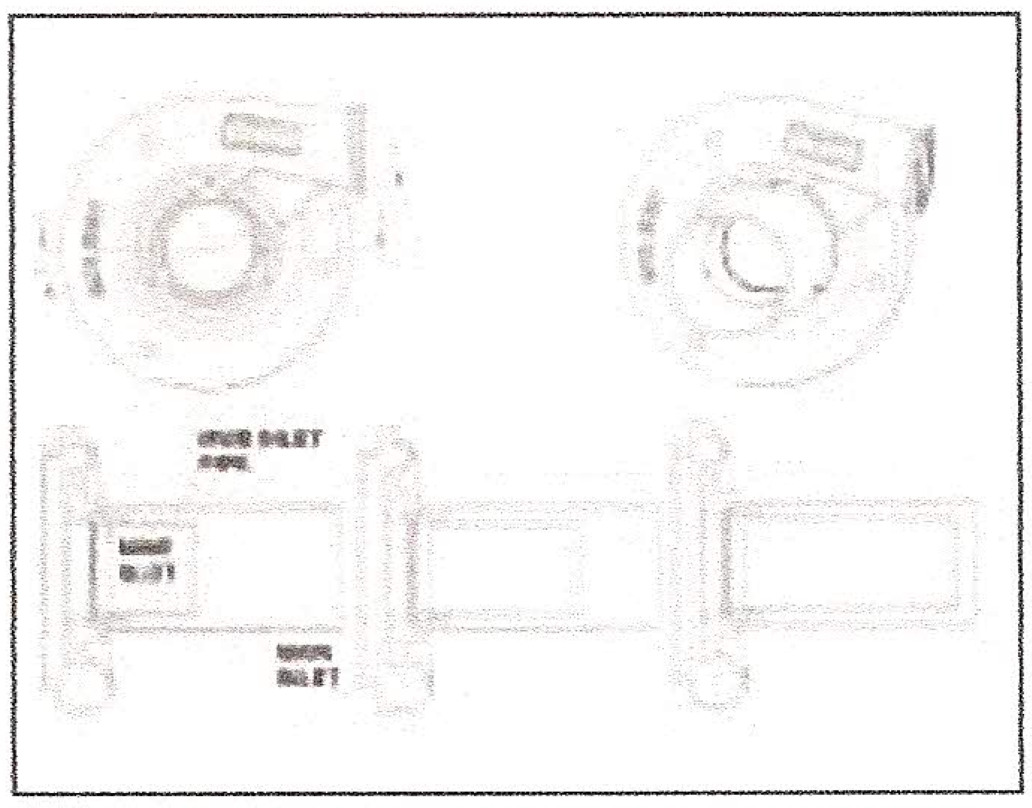


Fig 9 – Super MWE fabricated pipe extensions used for test validation

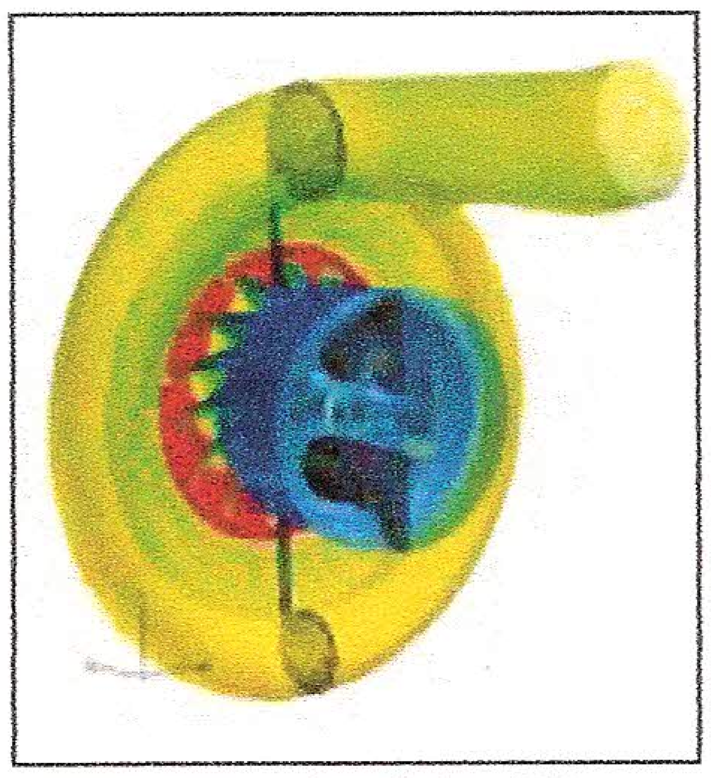


Fig 6 – Example of the CFD mesh used

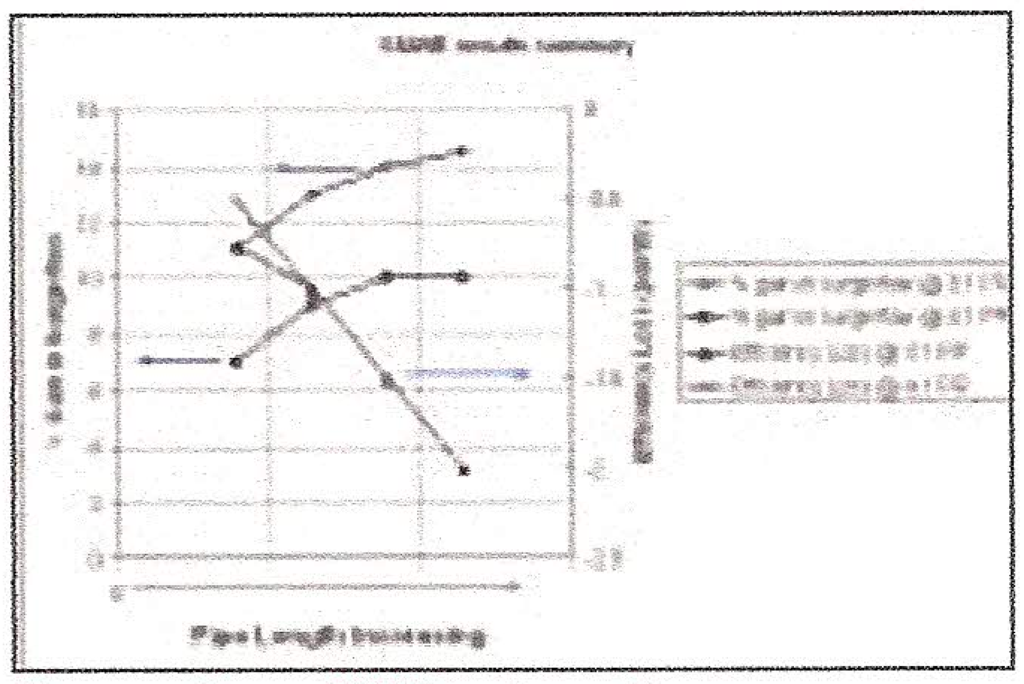


Fig 10 – Super MWE test result summary

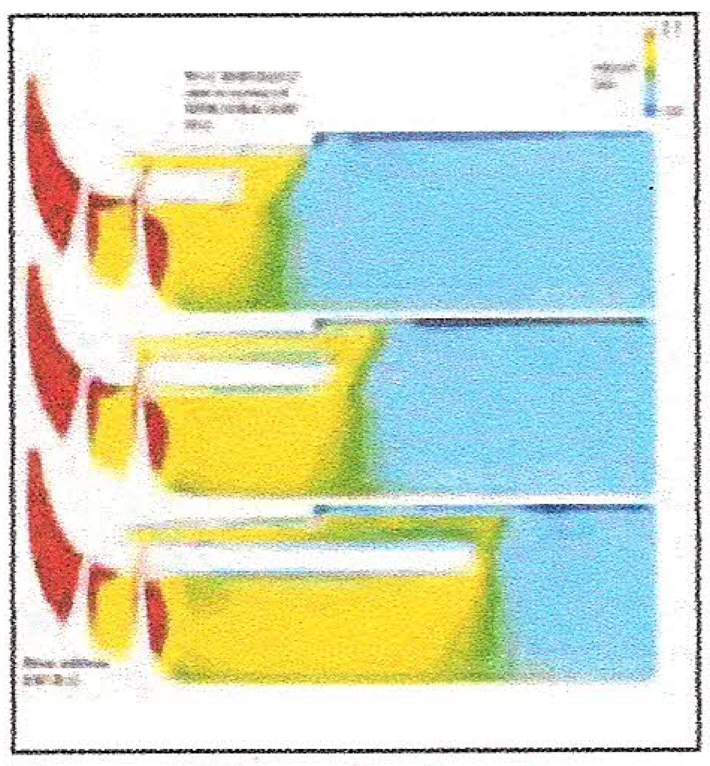


Fig 7 – CFD results for pipe extensions showing how Super MWE works

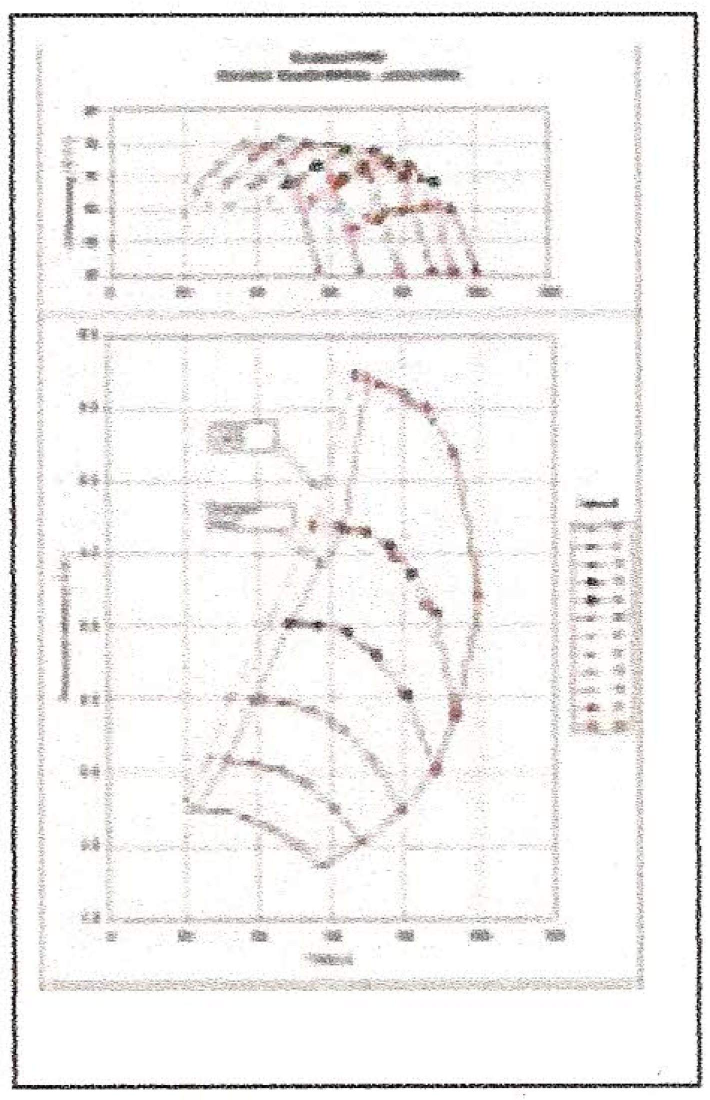


Fig 11 – Super MWE performance map comparison