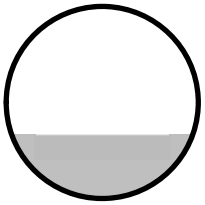
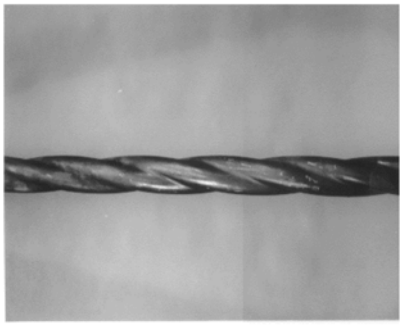
Innovative ducts for particle laden liquids

Cylindrical pipes are the natural choice for transporting liquids. The shape offers no hindrance to the liquid and the friction factor is small. However, when particles are present in the liquid, the advantage becomes a disadvantage. Particles can slide to the lowest part of the duct, build up and eventually block the pipe. The suspension of the particles can be maintained by pumping the liquid at high velocity, but this increases the power consumed by the pump and attrition wear as the high-speed particles strike the walls of the duct.



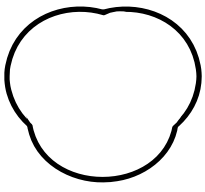
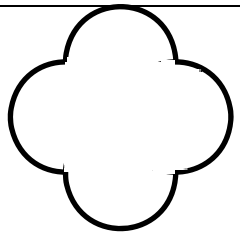
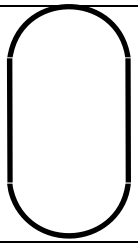
As far back as 1899[1], engineers realized that a twisting profile in the pipe would aid the suspension of entrained solid particles. Subsequently a variety of manufacturing techniques were employed to create this twisting profile in ducts and in 1940 an innovative 3-lobe pipe for boiler tube was invented by E.F.Spanner[2] . The lobed profile could be obtained by cold-forming circular tube with special dies. The lobed design also proved effective for transporting particle-laden liquids and a patented 4-lobed fixed frequency design[3] has shown improvement over the boiler tube design in swirling action for this purpose.



The 3-lobe duct of E.F.Spanner

The 4-lobe fixed frequency duct

A 2-lobed design, although marginally less adept at swirling the liquid causes a lower pressure drop across the duct. It is considered the best design for gathering settling particles and swirling them into suspension.

		
3-lobe section: **Large capacity for settling particles and lowest pressure cost but poorest swirling action.**	**4-lobe section:** **Most efficient swirling action but largest pressure cost.**	**2-lobe section:** **Similar swirling action to the 4-lobe but smaller pressure cost and good for settling particles.**

[1] Gordon, H.M. and H.A.(1899), Conduit or Pipe, US Patent Number 630605, 8th August 1899

[2] Spanner, E.F., (1940,1945), British patents GB521548, 24th May, 1940 and GB569000, 30th April 1945

[3] Jones,T.F. *et al*, Duct with Spiral Groove, European Patent DK1497564 (T3)-2009-04-06

Solid Body Model

Quite apart from the number of lobes, the most effective way to improve swirling action is to impart a slowly increasing angular momentum to the liquid. Earlier fixed frequency ducts tended to constrain the rotational flow of the liquid.

Researchers have found that for most of a duct cross-section, rotating flow acts like a solid body. The analogy of a flywheel with viscous friction gives us a simple model for a design in which the rotational momentum increases naturally. The constraining effect of earlier designs is neatly avoided.

Fluid in the duct takes time to respond to twisting action and this response can be predicted using the *Solid Body Model.* The outcome of these calculations is a time constant, τ, a unique value for each application. When combined with the mean pipe velocity u we have a 'distance constant' τu. It is this value which helps us to recommend the length of the swirl duct for best results. After a distance of $3\tau u$ metres the fluid will have reached near-optimal rotational velocity.

Duct Design

Requirements for efficient ducts differ according to the size of the solid particles, the carrying liquid, the diameter of the main and the required flowrate. Given the engineering details of the problem, main stages in its solution are as follows.

1. We test a small sample of the particle-laden liquid in a special cell apparatus to determine the total twist required in the duct to promote optimal suspension of the entrained particles.
2. We advise on the optimum ($3\tau u$) length of the duct. Shorter lengths are feasible (to fit within fixed dimensions for example), but with less efficient generation of rotational flow.
3. We design a continuous duct to create an efficient and increasing rotational momentum in the particle-laden liquid.

Please Contact TFJ Consulting Ltd. to discuss your requirements.