Rifled Rotation in Turbulent Cylinder Flow (20/11/13: www.gavinhamilton.ca,)

– "The best laid plans of mice and men gang aft agley," Robert Burns –

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Circa 1972, while contemplating why turbulent flow in a compliant cylinder (an artery) would exhibit simple harmonic dilations and contractions, when turbulent flow was considered as synonymous with chaos, I wondered if the irregular frosted glass appearance of an efflux jet from a straight glass cylinder would exhibit some recognizable wave pattern with freeze-frame photography. This essay reveals true previously unpublished details of the experiments that became engraved on my memory.

Because of the apparatus and space requirements for a standard laboratory set-up for cylinder flow studies, I decided on a miniaturized experiment, using a disposable small calibre (23 gauge) hypodermic needle with an attached polyethylene tube (a disposable "butterfly needle), with a friction-held end connector to a 60 cc disposable syringe. The inverted syringe, filled with a densely blue non-particulate dye (indigo carmine) was part of the pump apparatus for the injection, using a homemade foot-operated lever mechanism to depress the syringe plunger (CMAJ, 1972), to achieve a high pressure injection and to maintain a turbulent flow rate through a small diameter cylinder.

The needle was firmly mounted on a microscope slide fixed to a simple platform.

The hospital photographer, Jim Newman, had a bright modern photography room, with a well-equipped darkroom, to service the needs of the hospital medical staff, for the photographs and slides to be presented at hospital rounds. The room was immaculate and dust-free, with the walls in a gleaming pale cream and a brilliant white ceiling. As usual for his photo-lab work, he wore a hospital-issued white starched and neatly pressed lab coat. It was an era in the practice of medicine when white shirt, tie, blue blazer and grey flannel trousers were de rigueur.

With my shirtsleeves rolled up, I stood at the ready, with my foot on the foot-pump lever. Jim had erected a sturdy tripod, with his treasured Hasselblad camera macro-focused on the needle, with a Metz strobe flash that produced 1/50,000th second exposures and ready to take 2 photographs per second. He was primed to take macrophotographs starting the instant I stepped on the pump lever. The stage was set. The experiment was about to begin.

A sequence of a rapid succession of periodic flashes and camera clicks started the instant I stepped on the foot pump lever. Almost at once, there was a sudden POP! The polyethylene tube disconnected, flailing and squirting out the contents of its distended tube, while the jet of the syringe contents blasted off the needle mounting apparatus, spraying a cloud of spatters all around.

Just after the POP, Jim uttered a loud guttural gasp.

My initial startled silence was shattered by my laughter, which soon progressed in a crescendo to become a roar.

Slowly, Jim snickered. Then he chuckled. Finally he, too, broke up into a fit of uncontrollable laughter.

Finally a sense of reality slowly descended on the scene.

We looked at each other's blue spattered face, the unbelievable dissemination of dye spatters on Jim's immaculate lab-coat, on my shirt, tie and trousers, on the walls and ceiling – and on the lens and body of Jim's beloved Hasselblad. It was inconceivable that 60 ml of blue dye could extend so far, creating a scene of such chaos.

I commented: "Jim, we'll have to make a few adjustments in the experimental method."

A trained laboratory scientist witnessing the collateral damage from my first venture into the realm of independent pressure-flow experimentation might have wryly, sarcastically and justifiably commented: "I think this guy would use a sledge hammer on a thumb tack."

Jim's expression had gradually transformed from amusement to somber sobriety as the reality sank in – as his thoughts drifted towards the wording he would require to fill out another hospital requisition, this time to justify having his photography lab repainted – one month after the application of a beautiful fresh coat of paint.

My thoughts, however, gravitated towards a salvage mentality: what, if anything, would the photographs show?

Surprisingly, several clear, freeze-frame macro-photographs revealed – serendipitously – a smooth sharp-margined efflux jet, with a suggestion of a rifling effect. However, because the needle tip was beveled, the rotational pattern might have been created mechanically by a burred needle tip

margin. In this case, proving the induction of rifling in turbulent efflux jets, using a bizarre experimental method, while obtaining a fortuitous result, one is reminded of the fictional bumbling Inspector Clouseau ("The Return of the Pink Panther") who characteristically stumbled into crime-solving escapades.

Soon after, the failings of the original scientific method were addressed. Sequences of macro-photographs were repeated while using blunt-ended arteriogram needles of varying diameters, with the pump- and syringe-ends of polyethylene tubing that were firmly attached by Luer lock connections. A finely calibrated Harvard infusion pump replaced the primitive foot pump.

The efflux jets from arteriogram needles of different diameters displayed simple harmonic rifling wave patterns in turbulent flow – and even in transition – establishing that there was a generally unrecognized, or ignored, rifling in the turbulent efflux jets from cylinders of small calibre. The force responsible for the rifling may be attributable to entrapment, transverse reverberation and amplification of coherent ($n = v / 2d$) transverse sound, produced by the fluid dynamics of the flutter waves of transition to turbulence.