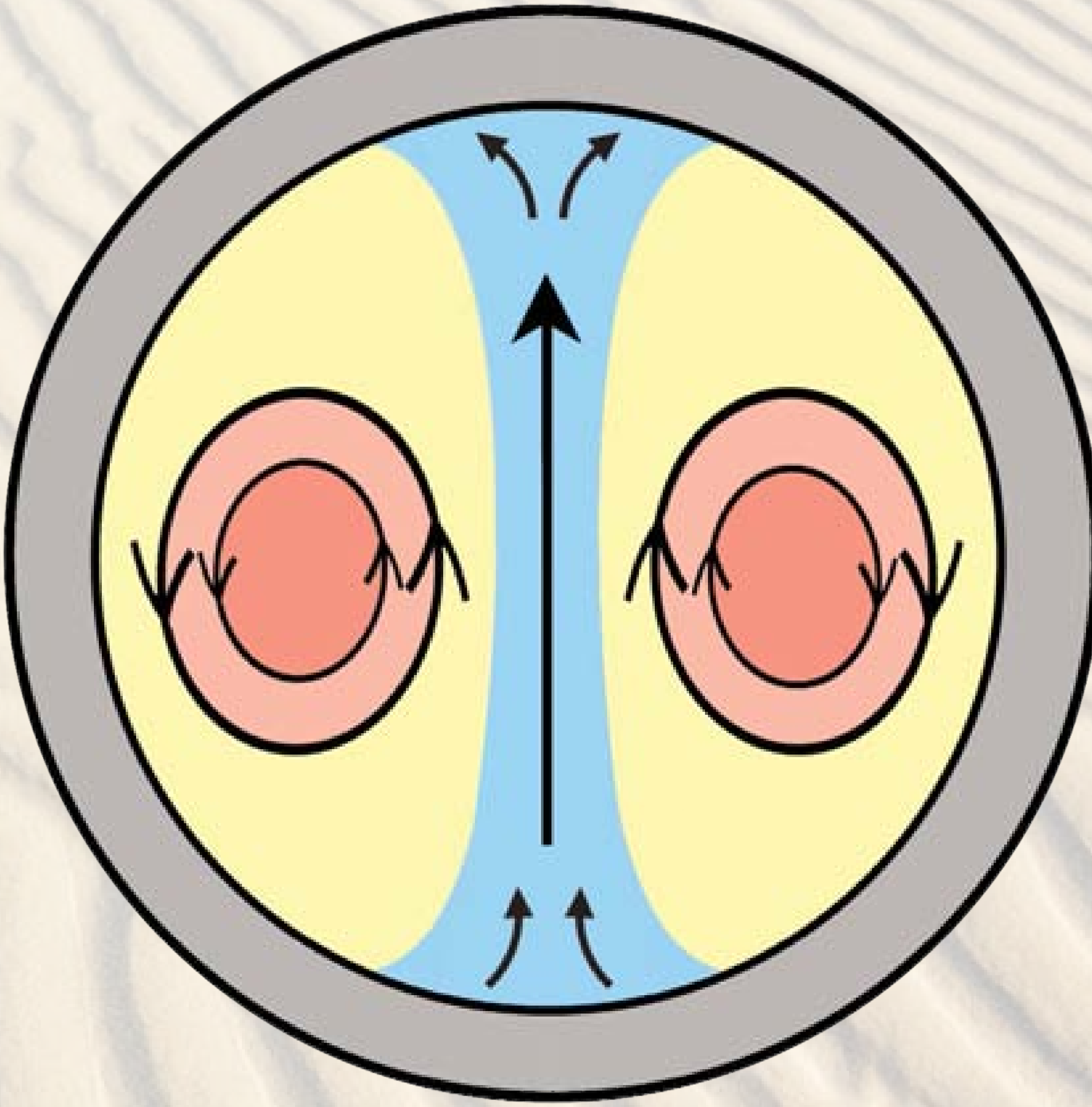
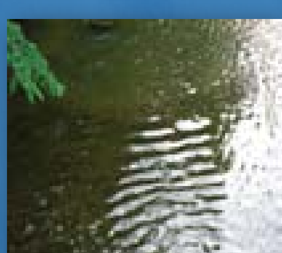
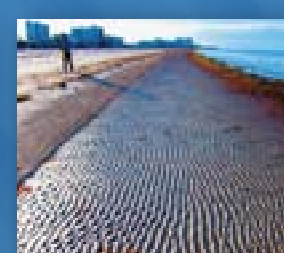
SIMPLE HARMONICS

Gavin Hamilton



SIMPLE HARMONICS

(January 2015 Supplement to Order in Chaos)

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Front cover image: Taylor's circulation in the cross-section of a curved pipe.

Simple Harmonics

"..instead of finding chaos and disorder, the observer never fails to be amazed at a simplicity of form, an exactitude of repetition and a geometric order."

(R.A. Bagnold 1941)

ABSTRACT

Stationary simple harmonic oscillations in a compliant artery (arteriographic standing waves) suggested sound waves (over 150,000 v.p.s. ultrasound) and coherent fluid shear waves, inspiring a theory that amplified shear-induced coherent sound energy from the dominant flutter waves of transition, causes turbulence, with resistance rising exponentially as the flow rate increases. Transverse coherent sound energy, as standing waves, freezes laminae, creating plastic flow longitudinally. In cylinders, longitudinally frozen laminae allow transverse streaming flows (in the plane of amplified reverberating sound) to display transverse flows in distinctive Taylor streaming turbulence units. In arteries, resonating transverse standing wave sound propagates longitudinally, producing simple harmonic arteriographic standing waves, with the now non-laminar fluid flowing like toothpaste.

KEY WORDS

Boundary layer flutter waves, coherent ultrasound, head-over-heels vortices, laminar interlocking, plastic plug flow, simple harmonic sound, Taylor turbulent streaming flow units, transition, turbulence

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INTRODUCTION

A 1957 radiograph introduced simple harmonic waves that implicated sound, fluid shear and compliant boundaries (Hamilton 1974). The unusual phenomenon of simple harmonic (SH) stationary waves in a compliant cylinder (an artery), during a rapid injection of a radiopaque iodinated contrast agent suggested coherent fluid waves (“arteriographic standing waves”) coexisted with similar stationary sound waves revealed in the obvious stationary periodic, equal, high and low pressure zones reminiscent of the Kundt’s tube experiment (Kundt 1866) of pre-university physics.

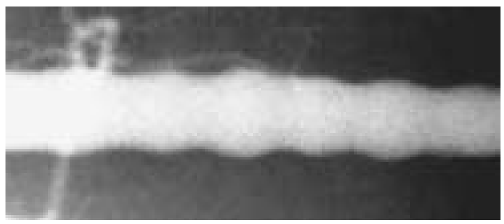

Figure 1: arteriographic standing waves

Sound energy triggers turbulence in laminar flow at transitional (“sound sensitive”) flow rates. During an orchestral performance, Leconte (1858) observed certain musical notes causing silently burning laminar coal gas jets to become noisy (“flare”) and drop in height (“duck”) from increased flow resistance, characteristic features of laboratory burners as laminar flow changes to turbulence.

Because musical notes incited turbulence, Tyndal (1867) deduced that specific “sonorous vibrations” (simple harmonic sound) triggered turbulence because coherent soundwaves amplified similar fluid shear waves created by friction along the tube walls. Other scientists found similar effects in unignited jets and in liquid jets, most pronounced with sound transverse to the flow.

TURBULENT FLOW IN TUBES

The unifying Taylor turbulence unit

One single flow pattern comprises turbulent transverse flows in pipes. Taylor's unheralded 1929 streaming flow across a diameter was flanked by a counter-rotating eddy on each side in turbulent flow in a curved cylinder.

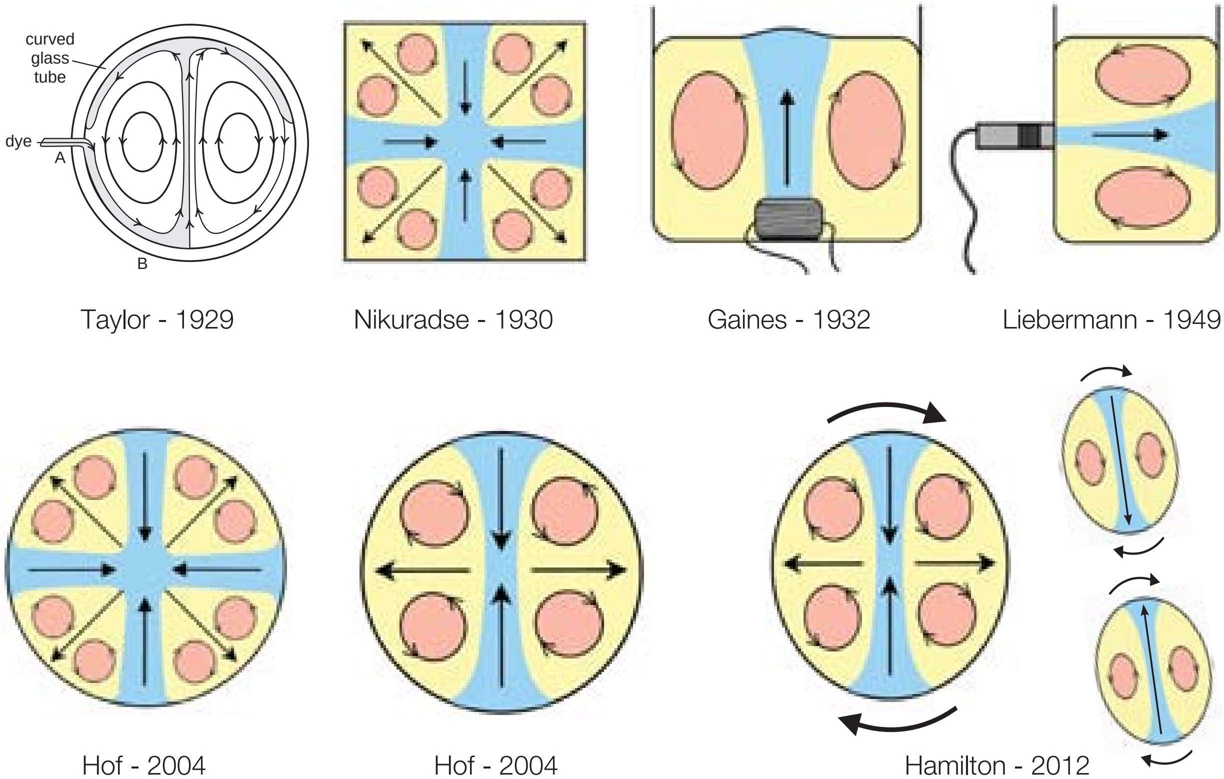

Figure 2: examples of Taylor's fundamental streaming pattern over many years suggest the physics.

Tyndall (1867), using a flat laboratory burner flame, demonstrated that specific coherent notes perpendicular to the flow triggered immediate turbulence. Simultaneously, the flame rotated ninety degrees, remaining turned until the sound ceased. This coherent-sound-induced rotation was used to explain the rifled rotation in jets from cylinders as turbulence onset. Entrapped echoing coherent transverse sound might be created in transition to turbulence *(figure 3)* (Hamilton 1980: pp. 59-61).

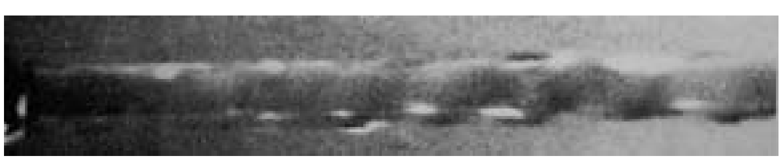

Figure 3: rifled spinning of efflux jet

Nikuradse (1930), studying turbulence in tubes with geometric cross-sections, described a pattern of adjacent identical segmental tranverse flows developing as turbulence onset: a streaming flow away from the midwall of each side, directed at the midstream, recirculating to the flow origin, with a mirror-image pair of entrained counter-rotating eddies, one on each side of the streaming. Nikuradse reasoned that the faster flows towards the corners were dominant *(figure 4)*. However, flows away from the midwall boundary, with the return flows accelerated by the convergencence of the corners, seem to be primary.

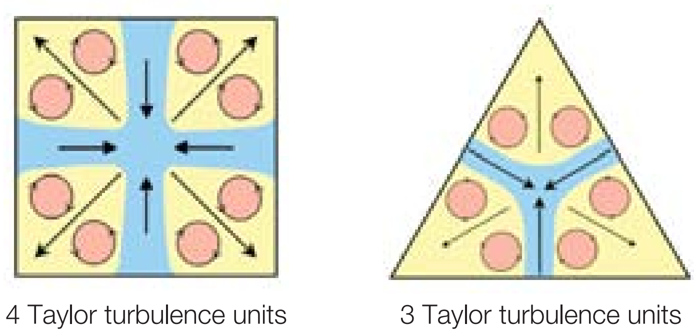

Figure 4: Nikuradse (1930)

Rifled rotation in cylinders in turbulence would prevent 1930 technology from demonstrating Nikuradse's expectected transverse streaming flows and mirror-imaged eddies found in geometric tubes.

Hof et al (2004) with SPIV (stereoscopic particle image velocimetry) computerized imaging, showed two, three, or more Taylor transverse streaming flow units in turbulance in cylinders. While inducing flows, ultrasound beams propel suspended particles in tight trochoidal paths (Liebermann 1949). If particles were chosen with the same characteristic acoustic impedance (CAI) as the fluid's CAI, sharper images should emerge (Hamilton 2011, p. 81), duplicating the idealized illustrations of Fitzgerald (2004) *(figure 5)*. Boundary layer echoing sound would pass through as if the particles were the fluid itself.

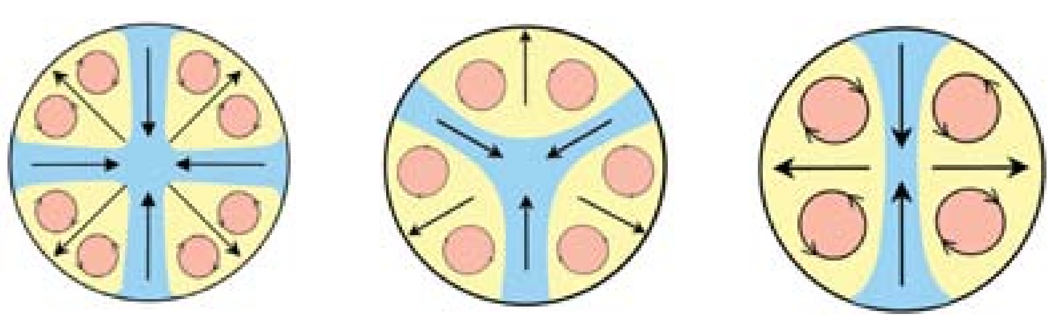

Figure 5: four, three and two Taylor turbulence units in cylinders (Hof-Delft, 2004)

Gaines (1932), using audible coherent sound and Liebermann with ultrasound (1949), displayed similar flow patterns – a central streaming flow away from the sound, with counter-rotating eddies mirrored on each side. These sound-induced flows duplicate Taylor turbulent units *(figure 6)*.

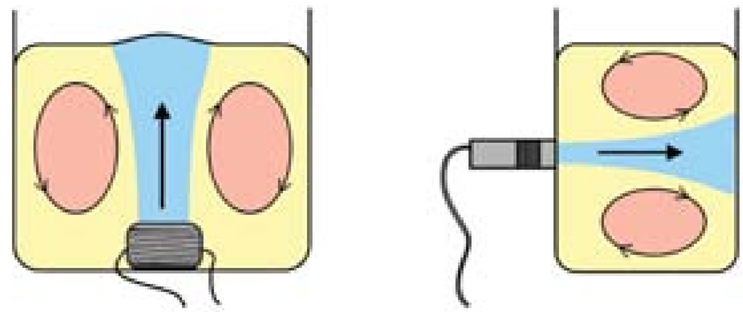

Figure 6: a physical cause of Taylor turbulent units (sound generators)

The similarity suggests coherent sound, generated in the boundary layer during transition to turbulence, creates the unifying flow pattern.

A Tyndall efflux jet, triggered into turbulence and spinning by a specific simple harmonic sound, could split into 2, 3, or more equal spinning jets. If turbulence and splitting involved a Hof-type 2-division variety of a spinning jet, specific coherent sound waves (a whistle), superimposed on similar sound waves generated in the boundary layer at each end of a diameter, might amplify the simple harmonic shear-flow-generated sound, causing it to split where the trans-diameter flows collide in midstream, resulting in two equal and spinning Taylor turbulence units, *(figure 7)* (Hamilton 2012).

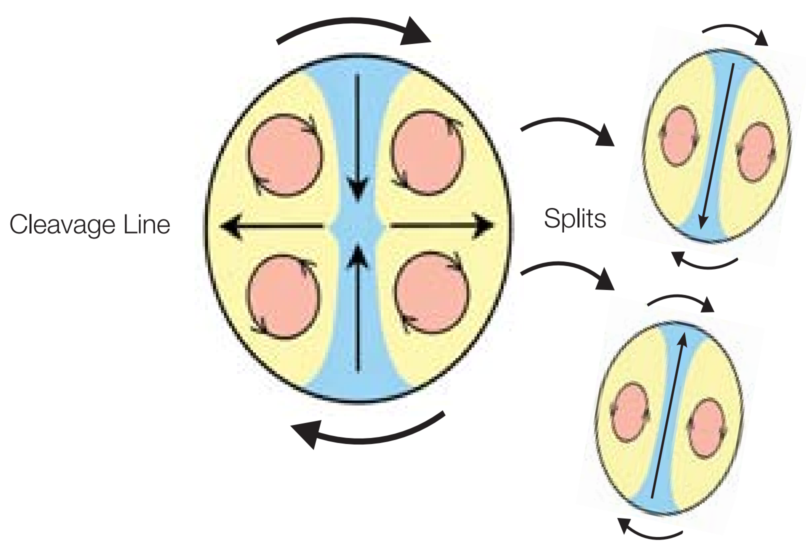

Figure 7: Tyndall's turbulent jet splits where two Taylor streaming flows collide (Hamilton 2012, p. 10).

Transverse flows in rectangular tubes with vertical standing wave sound

Rectangular silicone tubes create echoing reverberating ultrasound standing waves between a quartz ultrasound generator separated from a Pyrex roof by one wavelength (Bengtsson 2004). Reducing the tube height to ½ wavelength would create an echoing reverberating standing wave with one streaming flow from the base, striking a similar streaming flow from the roof at mid-point. Mirror-image entrained vortices developing on each side of each streaming flow duplicate Taylor turbulent units *(figure 8)*.

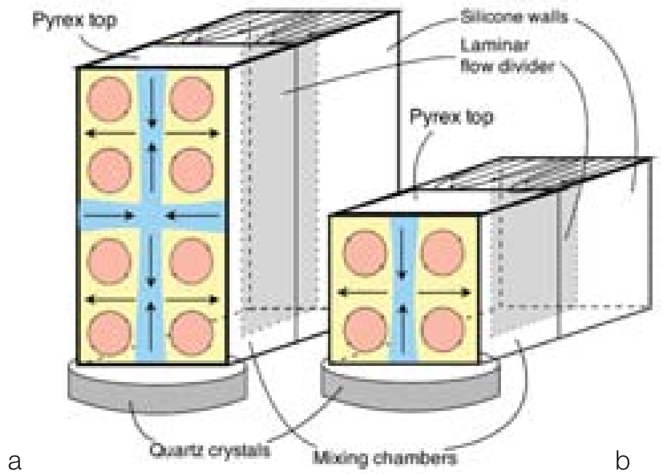

Figure 8: Taylor streaming flow units in vertical ultrasound standing wave fields (mixing chambers)

Replacing silicone sidewalls with rigid walls, entrapped sound would reverberate into echoing coherent standing wave sound transversely and vertically, creating four coherent-sound-induced Taylor flow units, reproducing Nikuradse's flows in rigid square tubes. Rounding off the tube's square corners, forming a cylinder, entrapped echoing standing wave sound would create streaming flows and mirror-imaged vortices of a four-division symmetric transverse flow pattern found by Hof et al in 2004 in cylinders *(figure 9)*.

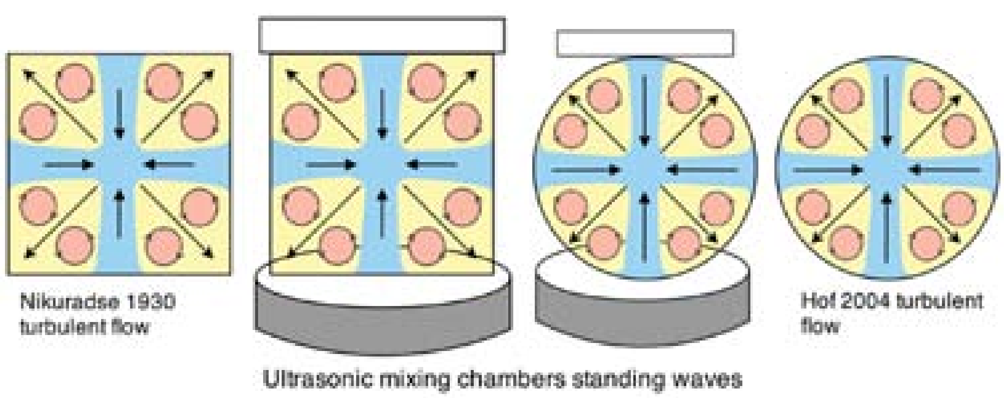

Figure 9: four similar Taylor flow units in square and round tubes

This suggests that turbulence in transverse flows in tubes results from amplified echoing transverse coherent sound – generated in the boundary layer by fluid shear.

Cylinders' isovelocity profiles

The parabolic isovelocity profile of laminar flow flattens in turbulence, the fluid flowing like plastic (longitudinally).

With a significant concentration of suspended particles of a particular size compared to the diameter (e.g. blood cells in capillaries), particles are displaced slightly away from the boundary, the particle-rich-fluid similarly flowing like a plastic plug.

Daily (1959) similarly described interlocking of a fluid column composed of suspended matter (a non-Newtonian non-laminar fluid): suspended paper stock fibers became interwoven, transferring the momentum equally across the fluid column, resulting in a flattened isovelocity profile. This effect (Fahraeus-Lindqvist Effect) is seen in small blood vessels, with the cells flowing collectively, physically interlocking the laminae, and creating a flattened isovelocity profile – like a plug of plastic, similar to turbulent flow *(figure 10)*.

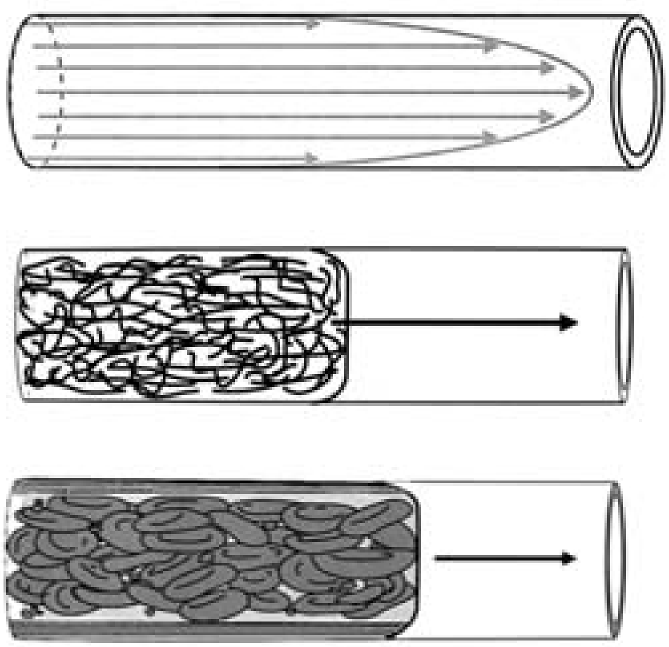

Figure 10: isovelocity profiles: laminar flow, the Fahraeus-Lindqvist Effect and turbulent flow

Transition to turbulence in cylinders is unique, creating transverse echoing and reverberating standing sound waves with a physics-imposed wavelength (λ) of two diameters. Turbulent water flow (velocity of sound = 1,234,000 cm per second) in a cylinder of 1 cm diameter equates to a resonant frequency (n) of 123,400 vps (v = nλ), ultra-high ultrasound.

Entrapped echoing *creates* coherent sound *causing* intense reverberation of molecules transverse to the laminae, freezing them, interlocked longitudinally (Hamilton 1980, pp. 69-71). Longitudinal interlocking should still allow transverse sound-induced flows in the oscillation plane, through longitudinally frozen laminae (Hamilton 2011, pp. 63-65), creating the 2, 3, or more transverse Taylor flow units found at Delft (Hof 2004). Hof's SPIV cross-sectional flows occur in laminar discs which conform to the shape of the flattened isovelocity profile. Laminar discs execute steady rotation, creating rifling of the turbulent column and efflux jet *(figure11)*. (Hamilton 2008 pp. 58-62).

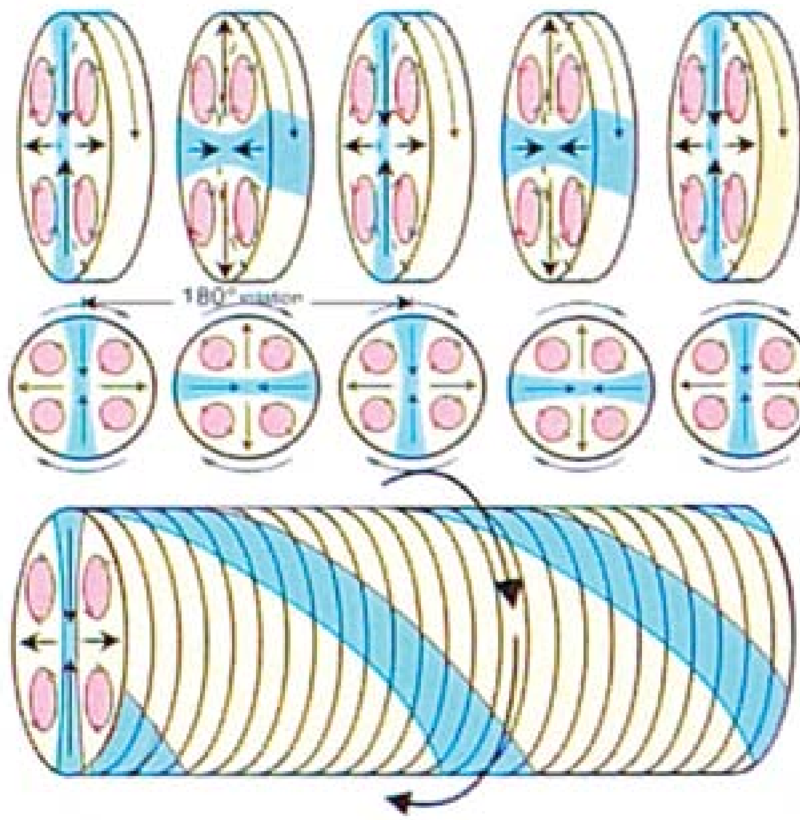

Figure 11: steadily rotating laminar discs containing Taylor transverse flow units

Taylor illustrated his characteristic transverse turbulent flow unit in a curved cylinder. Nikuradse hoped to find this pattern in turbulence in straight cylinders, but rifled axial rotation *(figure 3)* of a cylinder's turbulent flow column prevented its detection using 1930 technology. Centrifugal force in Taylor's curved cylinder would direct the fast-flowing midaxial stream towards the outside of the curvature where it remains, inhibiting rifled rotation, permitting 1929 technology to reveal it. Similarly, centrifugal force would cause transverse flows to emerge as, or coalesce into, one single central flow across the diameter, with mirror-image eddies – the Taylor, Nikuradse, Hof, Gaines and Lieberman pattern.

Tyndall's "Sonorous vibrations"

Tyndall (1867), in experiments on jets, showed that specific musical notes triggered turbulence, concluding that coherent sound waves became superimposed on similar simple harmonic waveforms generated by the jet's boundary layer friction during transition, amplifying them, precipitating turbulence at lower Reynolds numbers.

These are Tyndall's 1867 prophetic words – "Thus, the sonorous vibrations, by acting on the gas in the passage of the burner, become equivalent to an augmentation of pressure in the holder. In fact, we have here revealed to us the physical cause of flaring through the increase of pressure…" – followed by – "In the orifice of the burner the gas encounters friction, which, when the force of transfer is sufficiently great, throws the issuing stream into the state of vibration that produces flaring."

Simple harmonic waves create coherent sound and random turbulent spots, create noise. Sound created during transition is entrapped by cylinder reflectivity. Transverse sound becomes amplified in SH form with an imposed reverberating wavelength of two diameters. Resultant high-frequency high-energy oscillation of molecules transverse to molecular flow in laminae should inhibit their sliding on each other, abruptly freezing laminae longitudinally, creating a flat isovelocity profile coinciding with the onset of turbulence.

Compliant cylinder flows

The phenomenon of SH arteriographic standing waves (AGSWs) inspired this theory. AGSWs on a femoral arteriogram in 1972 recalled similar waves on a 1957 carotid arteriogram presented by renowned neuroradiologist Paul F. New, who transferred his fascination (New 1966) to me – an internal medicine resident on a neurology/neurosurgery rotation. New's standing waves demonstrated a paradox: SH fluid shear waves and simple harmonic standing wave sound in supposed turbulent chaos.

The high density of iodinated radiopaque x-ray contrast agents increases the characteristic acoustic impedance (CAI) of arterial fluid, enhancing wall reflectivity and entrapping flow-induced sound, particularly ultrasound with its high reflectivity. As turbulence erupts, laminar sliding is arrested abruptly and, with laminae frozen longitudinally, the radiopaque fluid flows like a plug of non-laminar toothpaste, creating orderly high/low pressure effects in a compliant tube (AGSWs) (Hamilton 2011, pp. 69-71).

SH long-crested shear waves along flat boundaries

Along flat plates, each lamina is a flowing planar sheet "membrane" of fluid mass. As distance from the boundary increases, laminae increase in velocity and momentum. A laminar shear layer acquires tension through Newtonian momentum-induced directional stability. Adjacent laminae share these momentum effects, resisting deformation, tending to rebound when the deformation force is released, initiating SH long-crested membrane vibrations. This explains Morkovin's axiom: "Like many other continuous systems, a shear layer is capable of natural oscillations around its mean state" (Morkovin 1958).

Tolmien (1929) and Schlichting (1933) predicted SH long-crested boundary layer oscillations during transition, from boundary layer frictional forces (viscosity), a form of grabbing and releasing, creating SH long-crested laminar deformities (waves). Amplification of transition's oscillations would trigger turbulence abruptly. Because other scientists failed to reproduce these oscillations, the theory became disregarded.

In wartime secrecy at the National Bureau of Standards in Washington, D.C., Schubauer and Skramstad (1943), meticulously designed a wind tunnel, suppressing external vibrations and internal mechanical vibrations, reducing unwanted environmental sound energy effects. Airflow studies along a flat shiny plate during transition proved, indirectly, the existence of SH laminar oscillations in the boundary layer by showing SH fluctuations in air laminar velocity. The velocity oscillations gradually decreased in amplitude as the distance from the boundary increased. Oscillations increased gradually, with a phase reversal, on crossing the zero-oscillation baseline plane *(figure 12)*.

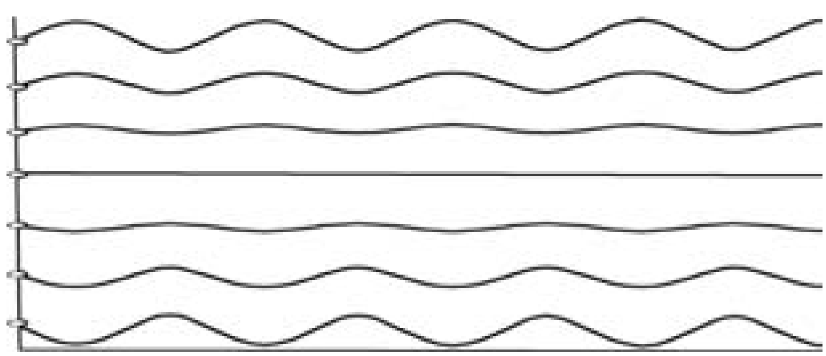

Figure 12: velocity oscillations

They concluded that the laminar oscillations would duplicate the velocity oscillations, reversing in phase on crossing the baseline. However, transition to turbulence is similar in incompressible liquids and liquid oscillations must replicate air oscillations.

Consider fluttering seesaw oscillations created by grabbing and releasing of a solid block sliding along a resistant boundary, with its axis of oscillation remaining in a flat plane. Imagine the block in the horizontal (neutral) position. Arcuate changes in forward velocity of the upper and lower anterior corners of the block will occur as the grabbing phase causes the anterior end to dip; the anterior superior corner will arch forward slightly, increasing forward velocity. However, as the inferior anterior corner dips, arching downwards and slightly backwards, forward velocity decreases slightly, a 180-degree out of phase relationship of velocity oscillations on each side of the zero oscillation axial plane.

However, tracings of the block's movements from a vertical array of equidistant points on the rear of the block create identical periodic in-phase sine waves from each tracing point from the boundary and across the axial plane *(figure 13)*.

Figure 13: seesawing block

Boundary layer oscillations develop similarly in air and incompressible water. Convergence and divergence of laminar oscillations might occur in air, because gases are compressible, but cannot in incompressible liquids. Divergence of laminae in out-of-phase boundary layer oscillations on each side of a zero-oscillation plane cannot occur in liquids without cavitation. Fundamental physics demands that identical in-phase sinusoidal boundary layer oscillations occur in all adjacent laminae in liquids and, therefore, in air (Hamilton 2011, p. 10).

The Schubauer and Skramstad velocity oscillations are not shear waves but graphical representations of laminar velocities at the levels of the equidistant hot wire anemometers in the boundary layer.

A spectrum of standing waves in transition to turbulence along a flat plate

Hold your right hand out, palm down, the fingers and thumb extended horizontally (as if flat on a table), creating one handbreadth. Imagine holding it just above a SH sinusoidal corrugated panel (like Benjamin's studies of pressure relationships in fluid shear waves, 1959), the rigid long-crested corrugated waves transverse to the handbreadth. The distance from mid wave-crest to mid trough is one handbreadth, the lateral margin of the thumb held just above the mid wave-crest and the lateral margin of the 5th finger similarly just above the mid trough, with the wrist at a similar distance above the wave-crests.

Imagine the hand floating ("flowing") horizontally just above the corrugated surface at a steady pace. The thumb, palm and 5th finger will be fluttering up and down coherently, just above the corrugated surface with the thumb and fifth finger duplicating its SH contours. The handbreadth will be oscillating like a seesaw, the axis in the mid-wrist moving steadily on a flat horizontal oscillation-free plane.

Holding the left hand similarly, the left thumb kept in contact with the right thumb and with the horizontal hands, moving together just above the waves and reproducing the contours of the SH wavy surface at the same steady pace, the hands will be oscillating coherently.

The movements of the joined hands will create SH fluttering oscillations like a standing wave in a skipping rope (or a musical string), with loops at both ends (where the holders' hands activate the rope)¬ and a loop in the middle. The two handbreadths represent one wavelength. The fluttering up and down movement of the thumbs and 5th fingers create SH vibrations (coherent sound) perpendicular to the steady horizontal movement (flowing movement), just as would a steadily moving musical string; the sound, generated transversely, is propagated in all directions. The standing wave sound generator (the seesawing hands) moves as a "travelling wave" at the speed of the fluttering hands. Thus we have physical standing waves in the moving two handbreadths – and we have "travelling" standing wave sound generated normal to the flow, by the fluttering up and down (seesaw movement), with a component of standing wave coherent sound propagated horizontally along the boundary.

The handbreadths duplicate the sinusoidal paths of the flow in each lamina in the boundary layer, fluttering up and down as boundary layer flutter (BLF) waves, each lamina following the same horizontal SH path, layer upon layer from the boundary.

The sinusoidal paths (the Morkovin Membrane or MM waves), along which each individual lamina will flow, are pushed by viscosity, sliding steadily along a smooth shiny boundary, more slowly than the laminae which snake along over similar adjacent interdigitating sinusoidal paths with SH rhythmicity as boundary layer flutter (BLF) waves, at the rate of flow determined by each individual lamina. The MM standing wave nature is revealed in shallow water when a transverse linear boundary deformity arrests the MM waves *(figure 14)* (Hamilton 2011, p. 57), and when they are associated with the development of similar sinusoidal long-crested waves on compliant non-laminar boundaries, like sand, or dolphin skin.

Figure 14: stationary standing waves in turbulent shallow stream flow.

Take a long thin longitudinal strip in a lamina, the width of laminar thickness (i.e. a laminar string). Move along the boundary at the speed of this lamina as it snakes (flutters) along and note its sinusoidal movements. The laminar string, moving at the speed of flow will duplicate the motion of harmonics in a musical string, with a series of loops and nodes. The standing wave sound, generated transversely (up and down) would be propagated in all directions, including along a hard sono-reflective boundary (Hamilton 2011, p.p. 13-21).

All laminar boundary layer flutter (BLF) waves (at the varying velocities of each lamina), strike simultaneously at the boundary in the grabbing (dipping) phase, and then lift up in the rebound phase. Coherent sound, although created transversely from the boundary, is propagated longitudinally in slowly moving SH waves of high and low pressure (Hamilton 2011, p. 57), consistent with a "travelling" planar standing wave sound field. The SH sound wave generation is inseparable from the SH transverse standing wave fluid oscillations (BLF waves) that generate the sound.

Compliant boundary (CB) waves

Incompressible liquid laminae can neither converge (compress) nor diverge (decompress), which would cause cavitation. Thus, SH boundary layer flutter (BLF) waves of transition along a rigid boundary must be accompanied by simple harmonic sub-BLF waves.

Schubauer and Skramstad, studying turbulence development from shear-induced SH boundary oscillations in air flow along a flat plate, considered whether these oscillations were manifestations of sound waves. With velocities far below the speed of sound, they discounted this idea. They did not consider "travelling" standing wave sound.

Transverse linear ridges on a shallow stream's streambed arrest slowly sliding boundary layer MM waves (figure 14). SH sand waves arrest and replicate the form of the MM waves. Bagnold's 1941 photographs of SH sand-wave formation during transition (in wind and water) show sand particles ejected from the troughs perpendicular to the flow (Bagnold: p.62) and deposited at shallow angles on the crests (as one would expect from Kundt's tube experiments, if a standing wave sound field were being generated by transition's shear forces). This supports the suggestion that standing fluid waves coexist with stationary sound waves. Coherent transverse sound, generated in the boundary, is the force ejecting sand particles from the streambed.

This might resolve Bagnold's (1941) dilemma after spending many years meditating on periodic waves in sand that are born at transition and persist and grow in turbulent flow: "....instead of finding chaos and disorder, the observer never fails to be amazed at a simplicity of form, an exactitude of repetition and a geometric order..." (Bagnold: p. xix; Hamilton 2008: p. 70).

Although long-crested flutter waves move at the rate of flow, the MM waves (the paths) and the sub-BLF waves, slide steadily, united in wavelength and velocity along a shiny boundary, but much more slowly than the average laminar flow. Along compliant non-particulate boundaries, periodic high-pressure bands (standing wave loops) create long-crested waves of surface depressions, while low pressure bands suck up the compliant surface (CB wave-crests), creating compliant boundary (CB) waves that replicate the wavy paths (MM waves) along which the BLF waves flow. The crests of the CB waves replace the sub BLF waves present along rigid boundaries *(figure 15)*.

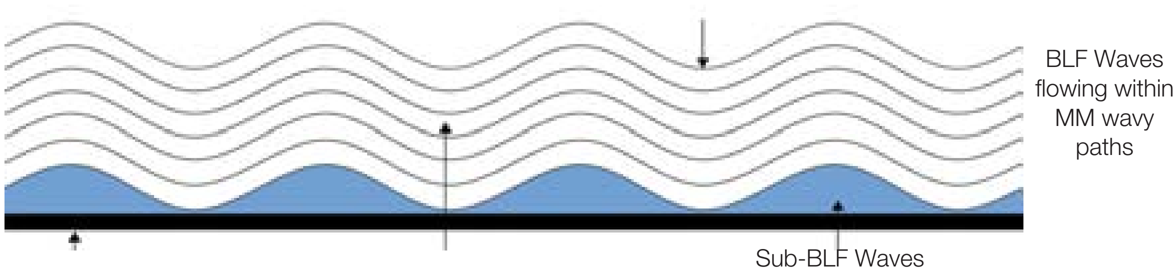

Figure 15: 3 types of shear waves along a flat plate

CB wave depth in wind over water disturbed Lock (1954) because of air's low density. As standing waves, the air waves derive added energy and high-pressure effects from the flow (Hamilton 2011, p. 61). Airflow viscosity entrains surface water, creating rotational flows as long columnar eddies under water wave-crests; these rolling columns arch over and crash on the shore as the lower margins slow on intersecting the sandy bottom in the shallows, accounting for the descriptive term "rollers" in older English lyrics and literature.

Tilting in the Reynolds (1883) U-tube standing wave experiment creates stationary boundary waves along the interface. Water flowing above, forms CB waves on the upper side of the interface. Inferiorly, carbon bisulfide forms similar underside water CB waves as it flows at the same speed, but opposite direction. Two adjacent atmospheric strata, flowing in equal and opposite directions (Hamilton 2011, p. 51), form stationary CB interstratum waves. CB waves developing between air strata emerge as clouds when there is sufficient temperature difference between the air masses to cause water condensation, creating SH long-crested cloud waves *(figure 16).*

Figure 16: simple harmonic interstratum shear waves

Invisible interstratum waves, Dowd waves (Hamilton, 2011, pp. 51-53) appear in clear skies, creating SH shuddering of aircraft and are sometimes revealed in lingering contrails *(figure 17).*

Figure 17: lingering contrail revealing Dowd waves

Dolphin hydrodynamics

Gray (1936) suggested the compliant dolphin epidermis delayed transition, permitting high-sustained speed with low energy expenditure. In testing compliant dolphin-like coatings, Kramer (1960) chose one particular silicone because of its standing-wave-sound-damping capability (Hamilton 2011, p. 47). His experiments suggested his dolphin-modeled coatings conferred a passive hydrodynamic advantage (distributed damping).

Disputed by some, other scientists support Gray and Kramer (Gad-el-Hak, 1996). Carpenter, Davies and Lucey (2000) extended laminar flow to high levels using damped periodic rigid panels.

Essapian's photographs displayed SH waves on dolphin skin during bursts of speed (figure 18), suggesting the waves might preserve laminar flow. Dolphins utilize arrays of pressure/vibration epidermal neurosensors to obtain sonar images (sonovision) that approach mammalian optic vision's resolution. Similar pressure/vibration sensors in the skin under the dermal ridges (which are aligned perpendicular to the flow) might control subcutaneous blood circulation in erectile "panels" (Essapian's 1955 CB waves) to damp shear waves actively. Similarly aligned compartmentalized bands of rheomagnetic fluid within compliant (e.g. Teflon) boundaries might generate similar fluid mechanics (Hamilton 2011, p. 47). GM automobiles apply electro-rheomagnetic fluid in shock absorbers to damp automobile oscillations.

Another neurovascular feedback mechanism might occur by cooling subcutaneous fat in bands aligned normal to the flow. Fear-induced vasoconstriction cools our fingers quickly. Mammalian fat is liquid at body temperature, but solid at butcher shop or seawater temperatures. Semisolid fat could alter epidermal compliance in bands (panels) corresponding to Essapian's speed-induced epidermal CB waves (or Carpenter's damped rigid panels).

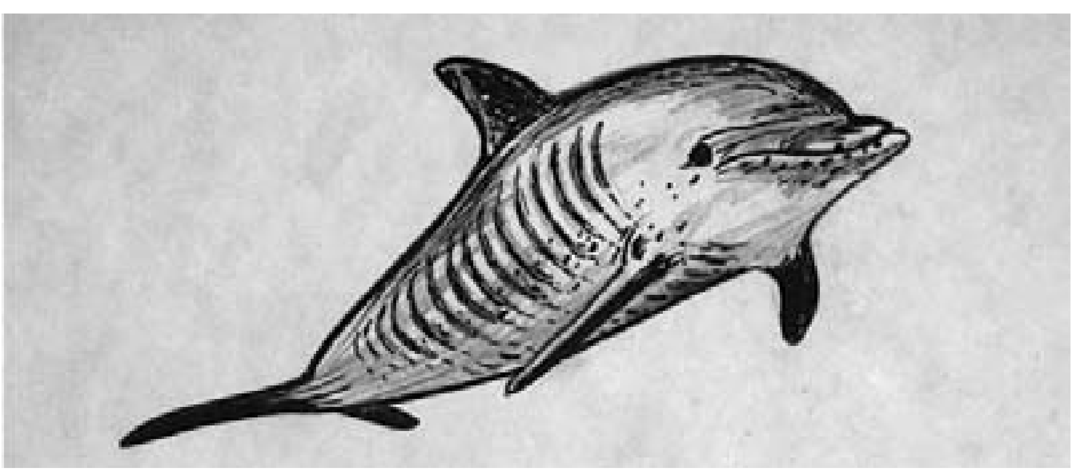

Figure 18: simple-harmonic dolphin epidermal CB waves

Edge tone physics

Edges cutting into jets trigger all incipient "turbulent sources" (Emmons 1951) (Reynolds 1883 "flashes of turbulence") of transition to erupt simultaneously along the edge, forming long-crested waves while producing simple harmonic sound (edge tones). Resultant powerful transverse sound interlocks the laminae and maintains them in BLF form within MM wavy paths in standing wave form.

CB sand waves emerge during transition and grow in turbulence, suggesting that sandy boundaries impose – and maintain – SH order on the otherwise randomness of turbulent spot emergence. Linear transverse streambed deformities unscramble, and force the re-alignment of the mélange of turbulent spots, torn off as spinning segments (vortices) from the original BLF waves of transition; the original SH waveforms of transition are reconstituted and may extend right to the surface in localized areas of SH surface water waves in an otherwise turbulent stream *(figure 14)*.

Simple harmonics at the molecular-atomic level

The current concept of the kinetic theory suggests that molecules are in constant random rectilinear motion, colliding with and caroming off each other in a chaotic mélange. Collisions with the water molecules in which colloid particles are suspended are believed to be the cause of the constant random zigzag particle paths described as Brownian movement. In this regard, contemplate the following analogy.

Consider a large motionless iceberg submerged in still water of the same specific gravity; it would hang suspended and stationary. If innumerable high velocity ice balls (the size of snow balls) were to pelt it randomly on all sides from all directions there would be an even force exerted on all surfaces because of the number, size, and randomness of the collisions. There should be no noticeable iceberg displacement. The pelting could not propel the iceberg through the mass and viscosity of water, in continuous knee-jerk zigzag displacements, many multiples of the iceberg's diameters.

Similarly, random collisions between innumerable sub-ultramicroscopic water molecules involved in random rectilinear motion would result in even pressure on all surfaces of a relatively much more massive Brownian particle. Particle displacement through water by many multiples of its diameters in erratic zigzag paths should not occur through these collisions.

One would not consider thermodynamics-mediated propulsion in the case of the iceberg – nor should one in the case of Brownian particle propulsion. Only Newtonian momentum-exchange physics in collisions between the particle and water molecules is under discussion.

Now consider the possibility that molecular kinesis in water is not translational, but is vibratory – involving simple harmonic oscillation of water molecules around their centres of mass (i.e., the atomic nuclei contained within each molecule's conjoined electron rings – with the amplitude of oscillation directly related to the Kelvin temperature). Collisions between abutting oscillating water molecules would result in caroming displacements and a "random walk" (similar to Einstein 1905) type of diffusion among molecules.

Now consider that molecular oscillation is secondary to simple harmonic oscillation of elemental atoms confined within the molecule by interconnected atomic electron rings. Atomic oscillation frequency could be atomic-weight-element-specific and pendulum-like (frequency is constant and independent of the amplitude of oscillation). The oscillation of element-specific negatively charged orbital electron rings and positively charged nuclei might generate a signature electromagnetic flux specific for each element on the periodic table; this mechanism might explain why heating of a substance to incandescence reveals an element-specific photon emission spectrograph (Alter 1854) a currently used method of chemical analysis.

The Kelvin-temperature-related simple harmonic oscillation of molecules may give insight into the physics of heat. Heat conduction transfer might be mediated by the summation of interference and amplification effects of the oscillation energies of adjacent interacting oscillating molecules either by direct vibrational contact or by the indirect conduction by convection currents. Thus, conduction is a mechanical transmission of vibrational heat energy; heat energy can also be transferred through a vacuum by radiant thermal energy as we feel in the radiant heat of the sun. However, we tend to neglect the radiant cold emanating from a cold wall in a warm room.

The physics behind Brownian movement has more than one facet. The diversity of ambient sound waves must contribute to the motion. A photon propulsion effect ("solar wind" and photometer mechanics) could contribute through the very lighting (and its reflections) used to image small particles. Other as-yet-undetermined physical processes may contribute, making the physics of Brownian movement not only compound – but complex.

Conclusions

The coexistence of coherent stationary shear and sound waves displayed on a 1957 radiograph (arteriographic standing waves) portrayed a paradox of simple harmonics in the expected chaos of turbulent flow.

Turbulence in tubes is defined by one, two, three or more similar Taylor streaming turbulence units directed perpendicular to the flow – a central streaming flow arising from the boundary layer, flanked by two similar, but counter-rotating eddies – a pattern identical to fluid flow produced from simple harmonic sound generators.

All shear-induced waves of transition along planar surfaces are created by simple harmonic boundary layer flutter (BLF) waves. They travel along slowly-moving simple harmonic Morkovin Membrane (MM) paths over similar boundary sub-BLF waves [or over compliant boundary (CB) waves], creating simple harmonic standing wave sound transverse to the flow, but propagated also along the boundary.

Amplification of the simple harmonic BLF-generated sound creates intense reverberation of molecules transverse to the laminae, interlocking them; abrupt boundary braking rips off random chunks of "frozen" long-crested BLF waves, causing turbulent spots of head-over-heels vortices (Hamilton 2011, pp. 65-67), producing noisy turbulence, not simple harmonic sound.

Damping the simple harmonics of the critical fluid dynamics flow zone, composed of integrated shear waves and sound waves of transition, should extend laminar flow, avoiding the exponential rise in resistance and energy expenditure of turbulence.

REFERENCES

Alter D., On certain physical properties of light produced by the combustion of different metals in an electric spark refracted by a prism. Am J Sc Arts, 18:55-57 (1854)

Bagnold R.A., The Physics of Blown Sand and Desert Dunes. Butler and Tanner, Frome and London 1971, reprint of 1941 edition 31-37 (1941)

Bengtsson M., Laurell T., Ultrasonic agitation in microchannels. *Anal. Bioanal. Chem.* 378, 1716-1721 (2004)

Benjamin T.B., Shearing flow over a wavy boundary. *J Fluid Mech.* 6, 161-205 (1959)

Brown G.B., On sensitive flames. *Phil. Mag.* 13, 161-194 (1932)

Carpenter P.W., Davies C. and Lucey A.D., Hydrodynamics and compliant walls: does the dolphin have a secret? *Curr. Sci.* 6, 758-764 (2000)

Daily J.W., Bugliarello G. and Troutman W.W., Measurement and analysis of turbulent flow of wood pulp fibre suspension. Ralph M Parsons Laboratory for Water Resources and Fluid Dynamics, *Massachusetts Institute of Technology, Technical Report* No. 35 (1959)

Einstein A., Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen., *Annalen der Physik*, 322 (8): 549–560. (1905)

Emmons H.W., The laminar-turbulent transition in a boundary layer. Part I. *J Aer. Sc.* 18, 490-498 (1951)

Essapian F.S., Speed-induced skin folds in the bottle-nosed porpoise, Tursiops truncatus. *Breviora, Museum of Comparative Zoology*, 43, 1-4 (1955)

Fitzgerald R. New Experiments set the scale for the onset of turbulence in pipe flow. *Physics Today:* pp. 1-5 (February 2004)

Gad-el-Hak M., Compliant coatings: a decade of progress. *App. Mech. Rev.* 49, 147 - 157 (1966)

Gaines N., A magnetostriction oscillator producing intense audible sound and some effects obtained. *Physics 3*, 209-229 (1932)

Gray J, Studies in animal locomotion. VI. The propulsion powers of the dolphin. *J Exp. Biol. 13:* 192 (1936)

Hamilton G., Coherent Sound Energy in Transition to Turbulence. UWO Graphic Services (2008)

Hamilton G. 1974 Patterns in fluid flow. Submission as work of original research in a gold medal competition for young researchers who recently passed the Canadian Fellowship examinations of Royal College of Physicians and Surgeons of Canada. p. 7 (available, without illustrations, at: www.gavinhamilton.ca)(1974)

Hamilton G., Patterns in fluid flow paradoxes – Variations on a theme, UWO Graphic Services (1980)

Hamilton G., The physics of the sound barrier, Brownian Motion and Tyndall's "sonorous vibrations." Aylmer Express (2012)

Hamilton G., Order in Chaos – The physics of transition to turbulence. Aylmer Express (2011)

Hamilton G., Coherent sound energy in transition to turbulence. Aylmer Express (2008)

Hof B., Van Doorne, C.W.H., Westerweeel J., Nieustadt F.T.M., Faisst H., Eckhardt B., Kerswell R.R., Waleffe F., Experimental observation during slow flow of non-linear traveling waves in turbulent pipe flow. *Science*; 305: 1594-1598 (2004)

Kramer M.O., Boundary layer stabilization by distributed damping. *American Society of Naval Engineers J.* 72. 25-331 (1960)

Kundt A.A.E.E., Über eine neue Art, akustischer Straubfiguren, und Über die Anwendung der zur Bestimmung der Schallgeschwindigkeit in festen Körpern und Gassen. *Annalen der Physik* 27, 497-523 (1866)

Leconte J., On the influence of musical sounds on the flame of a jet of coal gas. *Phil. Mag.* 15, 235-239 (1858)

Liebermann L.N., The second viscosity of liquids. *Phys. Rev.* 75, 1415-1422 (1949)

Lock R.C., Hydrodynamic stability of the flow in the laminar boundary layer between parallel streams. *Trans. Camb. Philos. Soc.* 50, 105-124 (1954)

Morkovin M.V., Transition from laminar to turbulent shear flow – a review of some recent advances in its understanding. *Trans. A.S.M.E.* 80, 1121-1128 (1958)

New P.F., Arterial Stationary Waves. *Amer. J. Roentgen*. 97, 488-499 (1966)

Reynolds O., An experimental observation of the circumstances which determine whether the motion in water shall be direct or sinuous, and the law of resistance in parallel channels. *Phil. Trans. Roy. Soc. Lond.* 174, 935-998 (1883)

Schlichting H., Über die Enstehung der Turbulenz bei der Plattenströmung; from Nachrichten der Gesellschaft der Wissenschaften zu Göttingen, *Mathematisch-Physikalische Klasse*, 181- 208 (1933)

Schubauer G.B. and Skramstad H.K., Laminar-boundary-layer-oscillations and transition on a flat plate. *Advance Confidential Report. National Advisory Committee to Aeronautics*, 1-70 (1943)

Taylor G.I., The criterion for turbulence in curved pipes. *Proc. Roy. Soc. London* 124, 243-249 (1929)

Tollmien W. Über die Enstehung der Turbulenz. 1. Mitteilung, Nachrichten der Gesellschaft der Wissenshaften zu Göttingen, Mathematisch – Physikalische Klasse, *Report I, Göttingen Scientific Society*, 21-44 (1929)

Tyndall J., On the action of sonorous vibrations on gaseous and liquid jets. *Phil. Mag.* 33, 375-391 (1867)

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In retirement, the author has continued

(1) to research and write about a potentially lethal toxic and allergenic natural rubber chemical, MBT (mercapto-benzothiazole), which continues to contaminate injections worldwide

2) to challenge – and put to rest – the persisting theory that the 1980-81 baby deaths at the Toronto Hospital for Sick Children were caused by digoxin poisoning and

3) to pursue a 40-year interest in fundamental Fluid Dynamics, expanding on his theory that coherent sound energy is responsible for the phenomenon of transition of laminar flow to turbulence, it having been a longstanding tenet in Fluid Dynamics theory that sound is an effect – rather than the cause – of transition to turbulence.

A book, "The Nurses are Innocent – The Digoxin Poisoning Fallacy" (Dundurn Press, 2011) – integrates the resolution of the first two problems.

This monograph, explains the author's theory of the physics behind transition to turbulence.