Redirect - Rebuttal Testimony of

Dr. C. P. Goodyear
and
Dr. C. C. Coutant

Direct Biological Effects on Entrained Fish Eggs and Larvae at Indian Point

February 22, 1973

TTTRAN

References:

(1) Testimony of Dr. Gerald J. Lauer (5 February 1973): "Effects of Entrainment on Morone sp. (striped bass and white perch) eggs and larvae at Indian Point"

(2) Testimony of Dr. Gerald J. Lauer (5 February 1973): "The Temperature Tolerance of Striped Bass Eggs and Larvae Relative to Their Seasonal Occurrence and Expected Indian Point Plant Discharge Temperatures"

(3) Testimony of Dr. Gerald J. Lauer (5 February 1973): "Studies of the Effects of Rapid Pressure Changes on Striped Bass Eggs and Larvae by New York University"

Direct Biological Effects on Entrained Fish Eggs and Larvae at Indian Point

In its rebuttal (References 1, 2 and 3) the applicant presented testimony relative to the staff assumption that of the striped bass eggs and larvae which pass through the IP plant a high proportion (perhaps approaching 100%) will be killed. It is the applicant's position that this value is much too high. The staff has evaluated the information which is presented in the February 5 testimony and concludes that there is no reason to change its estimate from 100% mortality, although the staff recognizes, as before, that this level of mortality may be somewhat high.

In his discussions (References 1, 2 and 3) of temperature tolerance of striped bass eggs and larvae relative to their occurrence at expected IP discharge temperatures, Dr. Lauer did not include any consideration of an increase in intake temperature which may result from the operation of plants on the Hudson River. The increased intake temperature will produce a comparable increase in the exposure temperature. Furthermore, the exposure time as presented in his testimony derives from the transit time through the IP plant of 11 min. while, by comparison, the data he presents uses a 60 min. temperature tolerance limit, which was believed to be quite conservative. The staff believes that the exposure time of 11 min. is very likely to be in error since striped bass and other fish leaving the condensors can be expected to react differently than a passive particle in the discharge canal. In particular, stressed fish tend to sound, i.e., move vertically downward when stressed. This response would tend to cause the larval fish to concentrate near the bottom of the discharge canal in areas with lower velocity than the median velocity in the canal. They may concentrate particularly in the distal end of the canal, near the discharge ports. A similar phenomenon seems to occur with *Gammarus* according to the applicant's testimony. Thus the exposure times of fish entrained into the plant may be considerably longer than either the water transit time or the 60 min. experimental period upon which Dr. Lauer's estimates are based.

In the comments on studies of the effects of rapid pressure changes in striped bass eggs and larvae (Reference 3), Dr. Lauer expressed the opinion that the effects due to pressure are not significant based upon pressure tests conducted by NYU and the apparent lack of any external clinical diagnostics (popped eyes, accumulation of gas bubbles, etc.) of gas disease either in the live or dead larval fish collected from various depths in the intake and discharge canals. It is the staff's opinion that the data presented by Dr. Lauer concerning this position are not applicable to the staff's conclusion. The NYU pressure studies did not include turbulence and shear as variables. Turbulence is particularly important because the formation of gas bubbles under supersaturated conditions is enhanced by water turbulence in the system. Thus if turbulence is not included as an experimental variable, it is less likely that rapidly decreasing pressures will cause bubble formation within the tissues. The effect of turbulence in a supersaturated system is analagous to that of shaking an opened bottle of soda pop to release the bubbles.

Furthermore, the likelihood of the gas bubbles forming and remaining in solution in the tissue of the fish is directly related to the delta T across the condensor. For most of the year for which the NYU data was gathered, the plant was operating with little or no delta T across the condensors.

It should also be noted that if Unit 2 operates with a bubble screen, as it is now directed to do by the state of NY, the problems with supersaturation may be greatly increased. There may also be an increase in the proportion of organisms which may be withdrawn with the condensor cooling water.

In the general category of pressure effects, the staff has included the disruptive forces acting upon suspended particles in fluid flow through tubes. Both turbulence and shear tend to deform suspended particles through the action of differing pressures upon various parts of the particle during its flow through the tube. Limited time has here-to-fore prevented the staff from making a detailed description of these effects. The section which follows attempts a limited summary in order to show that the applicant's rebuttal of the staff's position on pressure damage is simplistic and hardly applicable to the staff's conclusion.

Interesting responses are exhibited by particles suspended in a fluid that is flowing through a tube. These responses have been studied by many branches of science and technology: For example those interested in flow of dissolved macromolecules, of fiber suspensions in paper making, of latex particles in emulsion paints, of reinforcing particles in polymer melts, of rock crystals in molten lava, and of red and white cells in blood and in artificial kidney, heart and lung machines. A considerable body of empirical results and theoretical concepts has developed concerning these responses and the physical forces responsible for them (for example, see review by Cox and Mason 1971.

The most straightforward situation is one in which flow through a tube is laminar rather than turbulent. Even under laminar flow, any non-rigid particles suspended in the flow are subject to deformation. The deformation can be expected to become more acute as various degrees of turbulence are reached in valves, pumps, and elbows.

In any fluid flow in a tube there are forces acting upon particles that tend to cause the particles to migrate either toward the tube walls or toward the center. The direction of movement depends upon many factors, including fluid inertia, particle size, relative densities of fluid and particle, and shape of the particle (see, for example, Karnis, Goldsmith and Mason 1963). The same forces that cause rigid particles to migrate tend to deform non-rigid particles as well as to cause migration. The deformation then induces a different tendency to migrate, producing cumulative stresses that may cause the particle to break. Experiments by Rumscheidt and Mason (1961) and Torza, Cox and Mason (1971) have shown that in a local shear flow which is gradually increased, a drop of immiscible fluid deforms and breaks up in a manner shown in Fig. 1. The several cases illustrate various combinations of parameters.

The deformation of a flexible fiber in shear flow has been studied by Forgacs and Mason (1959 a,b). Increasing the length or flexibility of a fiber caused a progression of responses: 1) a springy behavior, Fig. 2a; in which the fiber buckles under compression in the shear, 2) a snake-like behavior, Fig. 2b, in which the fiber straightens itself periodically, 3) a permanent bending of the fiber into a helix, Fig. 2c, and 4) a complicated entanglement of the fiber, Fig. 2d.

No deformation studies of aquatic organisms have been conducted that compare with the detail of these fluid hydraulics investigations. Eggs and larvae would seem, however, to closely approximate the sizes, shapes, and general composition of many particles that have been studied. There is every reason to believe, therefore, that the conceptual and mathematical framework exhibited in the engineering literature for describing fluid flow and particle deformation would also apply to passing fish eggs, fish larvae and other aquatic organisms through the cooling system of a power plant such as Indian Point.

In summary the Staff continues to believe that damage to entrained larvae of striped bass probably will result in mortalities close to 100%. The causes of damage may be largely mechanical due to turbulence and shear within pumps and piping of the condenser cooling system. Additional stress will come from thermal and chemical effects.

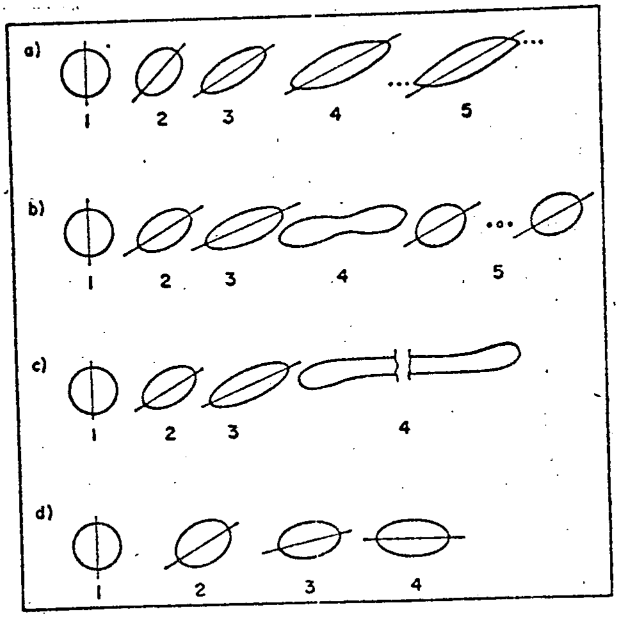

FIGURE 1. Tracings from photographs of drops in shear flow showing change in shape with increasing values of shear γ up to breakup. Cases (a), (b), and (c) are for $\lambda = 2 \times 10^{-4}$, 1.0, and 0.7 respectively. Case (d), for which no breakup was observed, is for $\lambda = 6.0$. After Rumscheidt & Mason (1961).

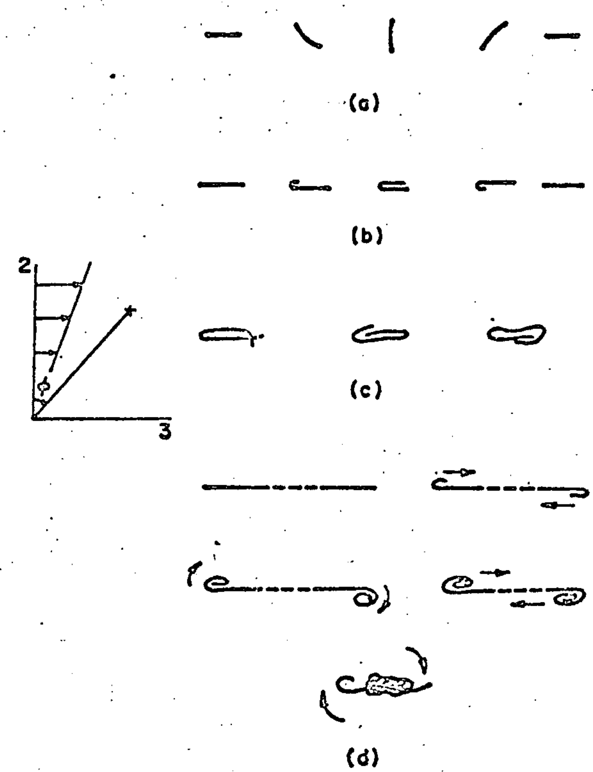

FIGURE 2. Tracings of photomicrographs of the orbits of flexible filaments viewed perpendicularly to the shear flow.

(a) Springy: Dacron rod with axis ratio 180 rotates in 23 plane and shows buckling under compression in the quadrant $-\pi/2 \leq \phi \leq 0$.
(b) Snakelike: elastomer filament of axis ratio 250 undergoes a snake turn.
(c) Helical: elastomer filament of axis ratio 330 no longer straightens out but assumes a coiled configuration: when viewed along the 2-axis it is seen to rotate like a helix.
(d) Entangled: a very long elastomer filament of axis ratio of approximately 800 forms a very complicated coil

After Forgacs & Mason (1959b).

REFERENCES CITED

1. Cox, R. G. and S. G. Mason. 1971. Ann. Rev. Fluid Mech., 3:291-316.
2. Karnis, A., H. L. Goldsmith, and S. G. Mason. 1963. Nature 200:159-60.
3. Rumscheidt, F. D. and S. G. Mason. 1961. J. Coll. Sci., 16:238-61.
4. Torza, S., R. G. Cox, and S. G. Mason. 1971. J. Coll. Sci., 26:
5. Forgacs, O. L., and S. G. Mason. 1959a. J. Coll. Sci. 14:457-72.
6. Forgacs, O. L., Mason, S. G. 1959b. J. Coll. Sci. 14:473-91.