the same as the external, then $\frac{dV}{dx}$ might $=0$, but this is liable to be disturbed by any casual sort of thing – so that it seems to me that for steadiness we must take the other alternative. The ~~factor~~ term γPV is a large one compared to the others unless u is large enough to be not at all negligible. In the limit, when the turbine is held fast, there is no doubt that $u^2 = \gamma PV$, and the pressure is not the external pressure – but that in the muzzle of a nozzle

(about 60% of the boiler pressure) and this is what the above reduces to if $T = 0$ (i.e. turbine stands still).

Does this appear to you to be right?

Love to Harriette &c.

your affectionate brother

Maurice F. FitzGerald

The thing corresponding to γPV in adiab^c. expansion of steam is too complicated to use.

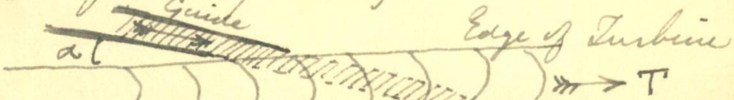
3? EGLANTINE AVENUE, BELFAST.

Oct 21st 1896

Dear George

I have been asked a question about steam turbines, with which a man here has been experimenting which has puzzled me somewhat to answer – it being "Is there any theoretical reason why a steam turbine can't be as economical as an ordinary engine?" The question amounts to this, though that isn't the exact way it was put.

Now treating the thing in a general way it appears that, barring friction, and assuming that the ultimate velocity of discharge is small enough to be negligible, there is no difference – I mean that no superheating of the steam appears bound to occur, as in the case of wiredrawing, ~~But~~ the steam is in the first instance wiredrawn by a nozzle, or guide, and then does work in the turbine. But if we consider matters farther, taking the figure to represent part of the crown of a Jonval turbine for simplicity, the shaded



part representing the absolute path of the steam, let x be distance measured along this path; let u be velocity of steam along x; let V be its specific volume; let T be the velocity of the turbine; let a be the area of the passage, taken normal to x; and let θ be the inclination of the path x to the plane of the turbine

so that initially $\theta = \alpha$, the inclination of the guides, and finally $\theta = \pi/2$ or thereabouts. Then, if further we treat the steam as if it were a gas expanding ~~with~~ so that $PV^\gamma = \text{const}$ (which is pretty nearly true) we have

$$\frac{dV}{dx}(u^2 - \gamma PV + Tu\cos\theta) = \frac{da}{dx}u^2(u + T\cos\theta) + VTu\sin\theta\frac{d\theta}{dx}$$

(which is got by putting $au = V$ in the equation of work done in passing thro' the turbine)

Now at exit from blades $\frac{d\theta}{dx} = 0$, as there is nothing to bend the path of the steam. $\frac{da}{dx}$ may not be zero, but could be compelled to be by little fixed vanes A in figure, and I can't imagine that they could <u>materially</u> alter the working of the machine; and if so, <u>either</u> $\frac{dV}{dx} = 0$ <u>or</u> $u^2 + Tu\cos\theta - \gamma PV = 0$, which reduces to $u^2 = \gamma PV$ if $\theta = \pi/2$. If the discharge pressure could be insured to be exactly