TRANSVERSE RESISTIVE WALL IMPEDANCE FOR SIS100 (AT GSI) AND LHC COLLIMATOR

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Slava is writing a Technical Proposal:
“The Transverse Damping Systems for SIS100&SIS300”

- **Comparison between Zotter2005 and Balbekov1985***

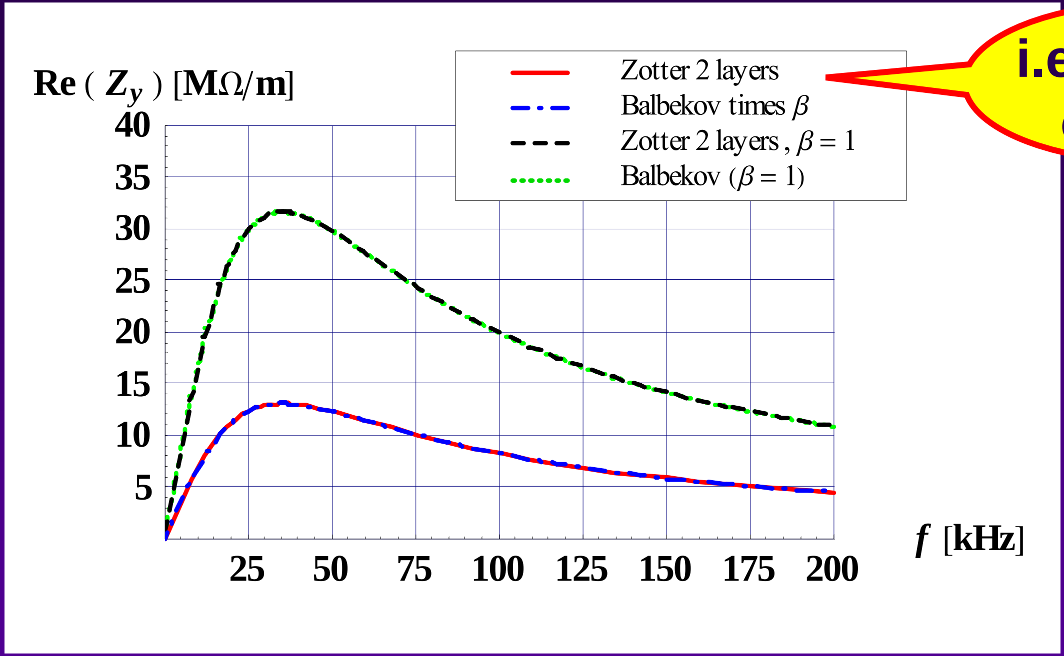
*** V.I. Balbekov, Space Charged Effects in UNK, in The IX All Union Conference on Particle Accelerators, JINR, Dubna, vol. 2, p. 360, 1985 (in Russian)**

Beam and machine parameters for SIS100

⇒ **Computation for $^{238}U^{28+}$ at injection, assuming (first) a round pipe with radius 32 mm (=vertical half axis)**

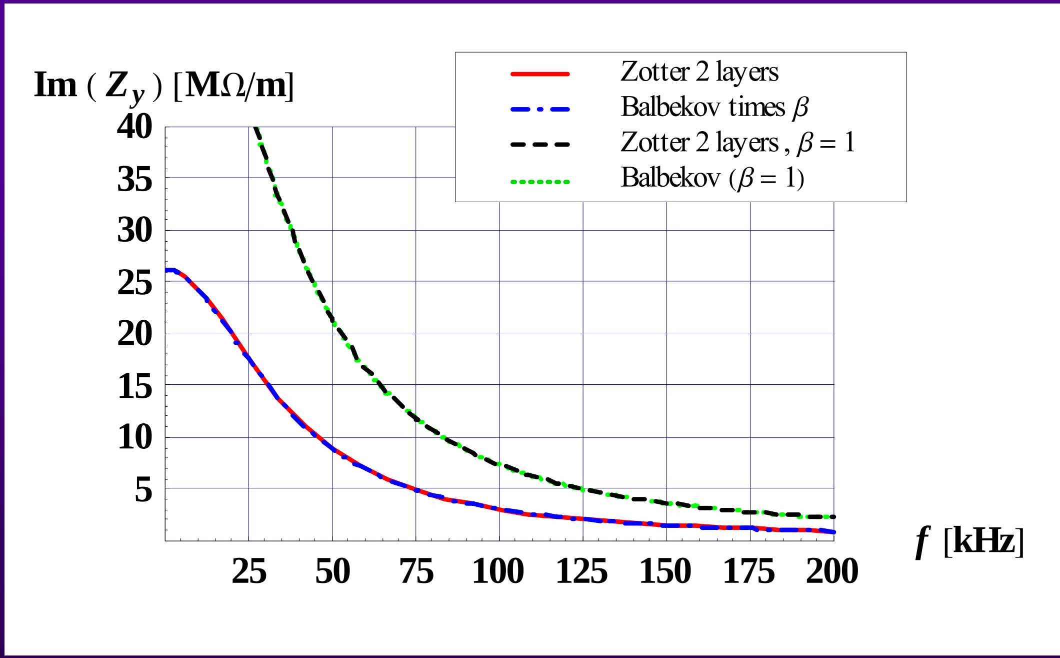
Machine circumference [m]	1083.6
Beam rigidity [Tm]	12
β	0.413
γ	1.098
f_{rev} [kHz]	114.4
ρ [Ωm] $\Longrightarrow$ SS	$9\ 10^{-7}$
Vacuum chamber thickness [mm]	0.2 or 0.3
Horizontal half axis [mm]	32 (65 normally)
Vertical half axis [mm]	32

Vacuum chamber thickness = 0.2 mm



i.e. vacuum outside

… assuming the whole machine circumference with the same resistivity

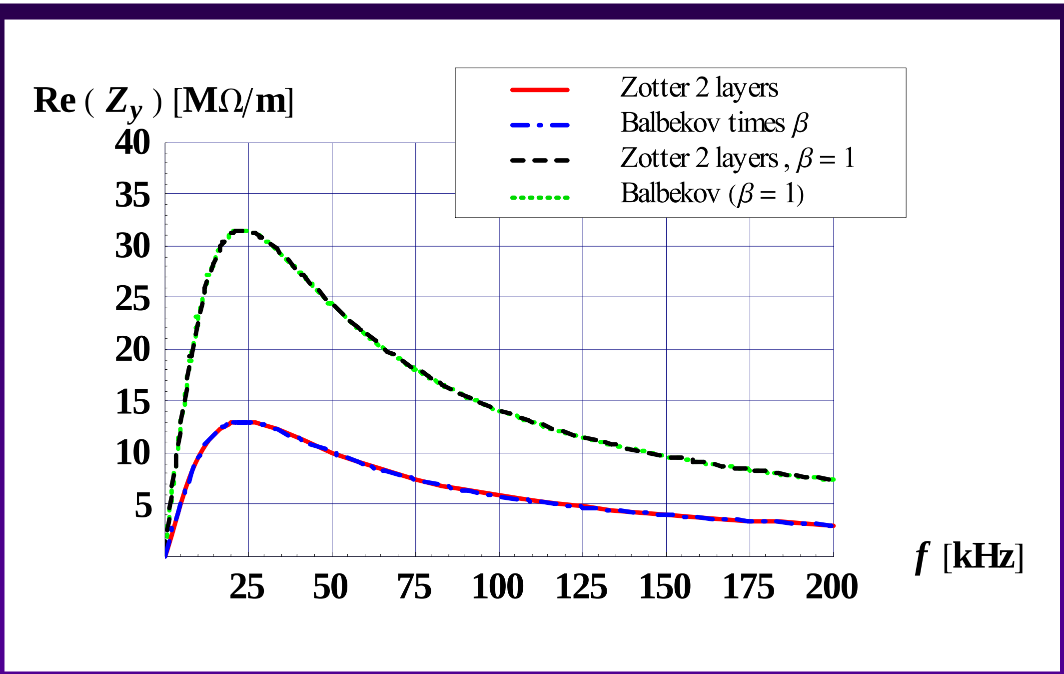


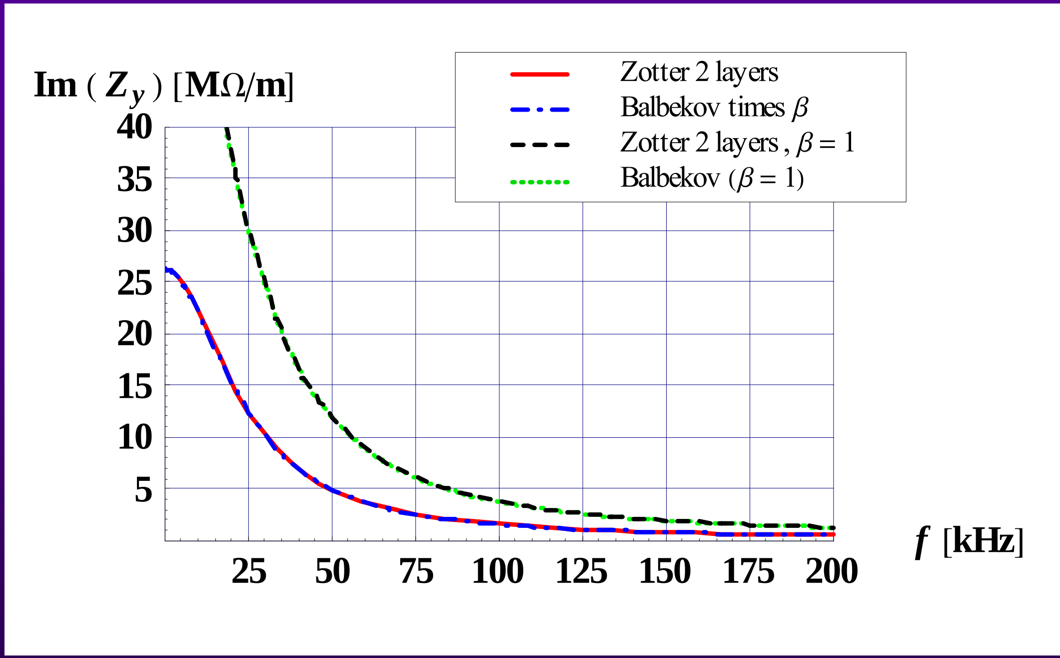
Skin depth = 0.2 mm

$\Leftrightarrow f = 5.7$ MHz

Vacuum chamber thickness = 0.3 mm

… assuming the whole machine circumference with the same resistivity





Skin depth = 0.3 mm

$\Leftrightarrow f = 2.5$ MHz

LHC graphite collimator

$L = 1 \text{ m}$

$b = 2 \text{ mm (half gap)}$

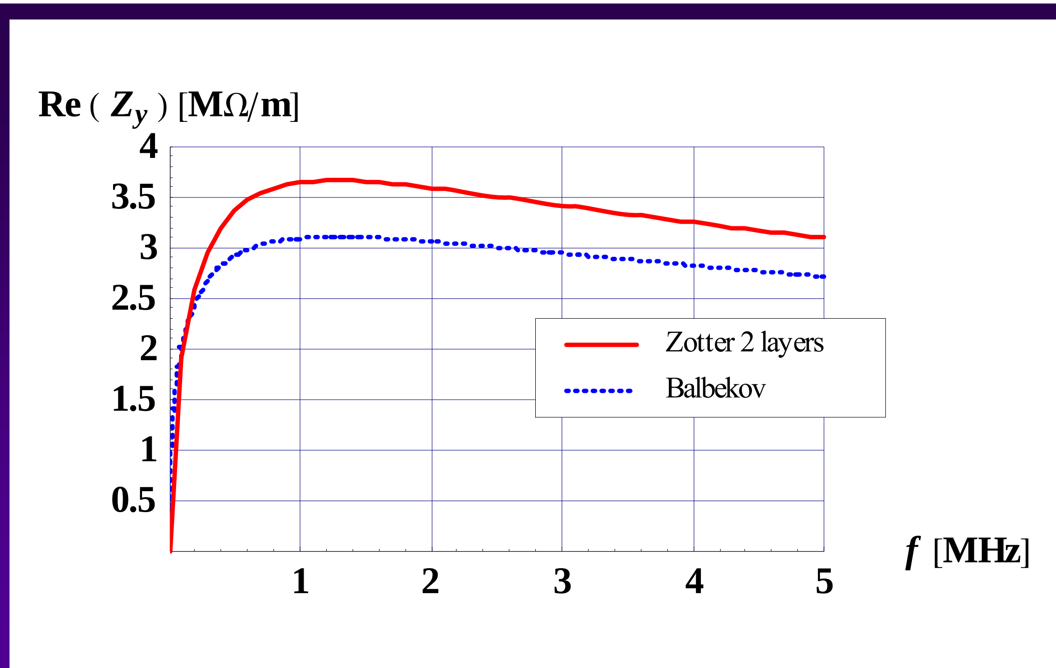
$\rho_C = 10 \ \mu\Omega\text{m}$

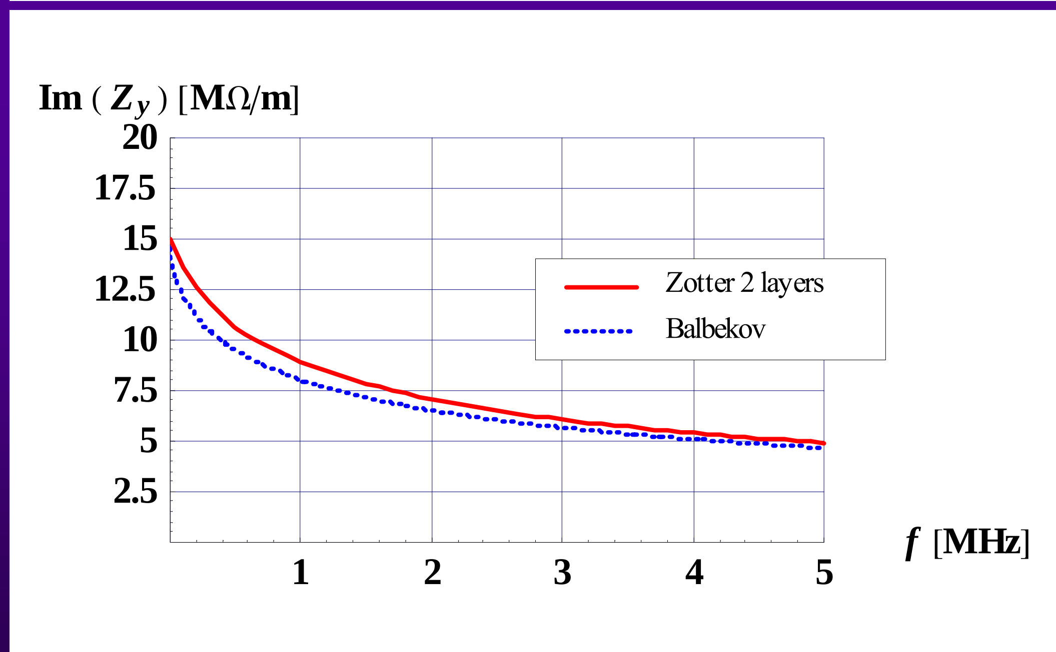
$d_C = 2.5 \text{ cm}$

$\gamma = 7462.69$

$\beta = 1$

Skin depth = 2.5 cm
$\Leftrightarrow f = 4 \text{ kHz}$





LHC graphite collimator

$L = 1\ \mathrm{m}$

$b = 2\ \mathrm{mm}$ (half gap)

$\rho_C = 10\ \mu\Omega\mathrm{m}$

$d_C = 2.5\ \mathrm{cm}$

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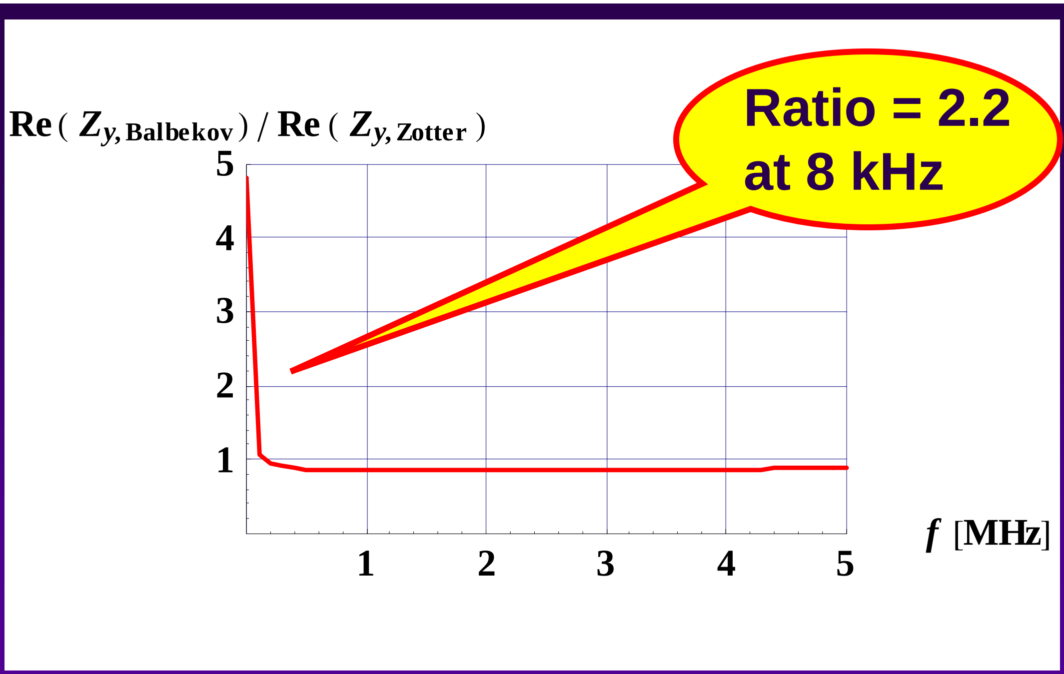

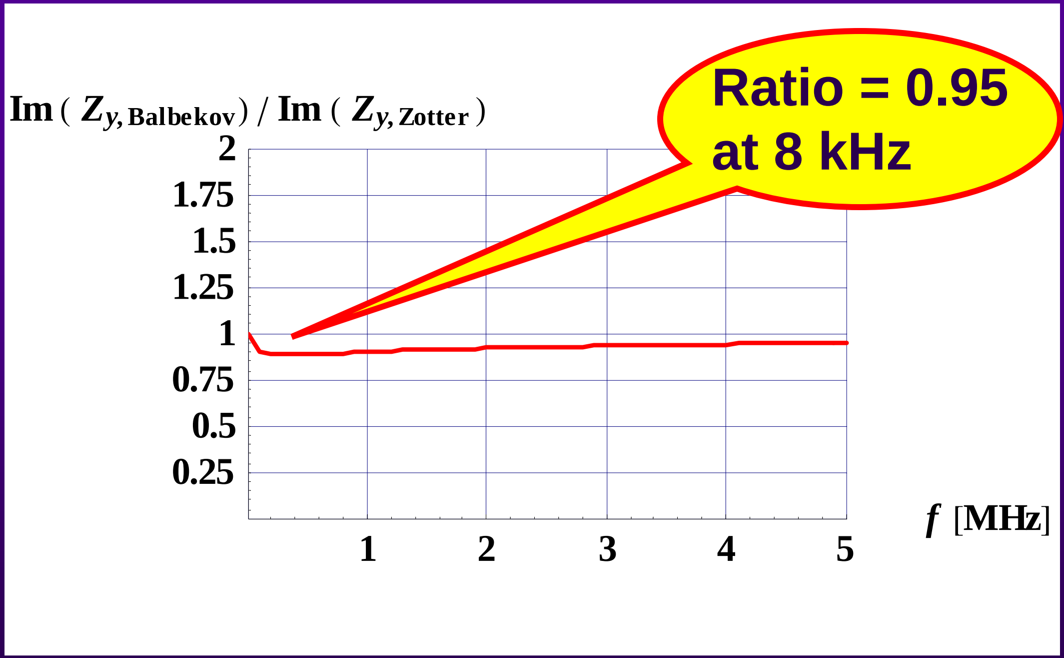

APPENDIX 1: BALBEKOV'S FORMULA FOR A ROUND PIPE

$$Z_y = \frac{j\,L\,Z_0}{2\,\pi\,b^2} \times \frac{1}{1 + \dfrac{b}{(1-j)\,\delta\,\coth\left[(1+j)\,\dfrac{d}{\delta}\right]}}$$

"Inductive-bypass" effect due to this term (⇒ 2 impedances in // as Vos2003)

where

$L = \text{Length of the object}$

$Z_0 = 120\,\pi$

$b = \text{Half gap}$

$\delta = \text{Skin depth}$

$d = \text{Thickness of the vacuum chamber}$

APPENDIX 2: Draft paper "Damping of Transverse Instabilities for Coasting Beams" by V. Kornilov, O. Boine-Frankenheim, I. Hofmann and B. Doliwa ⇒ Given to me (for comments) by Slava

No "inductive-bypass" term

3 Impedances

The transverse impedance due to the space charges (sc) we evaluate using

$$Z^{\perp}_{\mathrm{sc}} = iZ_0 \frac{R}{\beta\gamma^2}\left[\frac{1}{a^2} - \frac{1}{b^2}\right], \tag{29}$$

in which we take into account the elliptic cross-sections replacing the radii as $2a^2 \rightarrow R\left(\frac{\epsilon_{\mathrm{v,h}}}{Q_{\mathrm{v,h}}} + \sqrt{\frac{\epsilon_{\mathrm{v}}\epsilon_{\mathrm{h}}}{Q_{\mathrm{v}}Q_{\mathrm{h}}}}\right)$.

The impedance stemming from a resistive wall with thickness d_{pipe} we estimate [2] as

$$Z^{\perp}_{\mathrm{rw}} = \frac{2\beta c}{b^2\Omega} Z^{\parallel}_{\mathrm{rw}} = (1-i)Z_0 \frac{R\beta\,\delta_{\mathrm{skin}}}{b^3} \coth\left\{\frac{\Omega}{\beta c}\sqrt{\frac{1}{\gamma^2} - i\frac{4\pi\sigma\beta^2}{\Omega}}\, d_{\mathrm{pipe}}\right\} \tag{30}$$

($\delta_{\mathrm{skin}} = c/\sqrt{2\pi\sigma\Omega}$, $Z_0 = 4\pi/c$). Figure 4 shows this impedance in its dependencies on the coherent frequency Ω (left-hand side) and on the wall thickness d_{pipe} (right-hand side). The parameters taken correspond to a U^{28+} coasting beam at the injection energy, see Table 3 and Table 4 in the Appendix. The right-hand side plot is made for the frequency 156 kHz, the corresponding skin length is $\delta_{\mathrm{skin}} = 1.1$ mm. For the left-hand side plot, the skin length

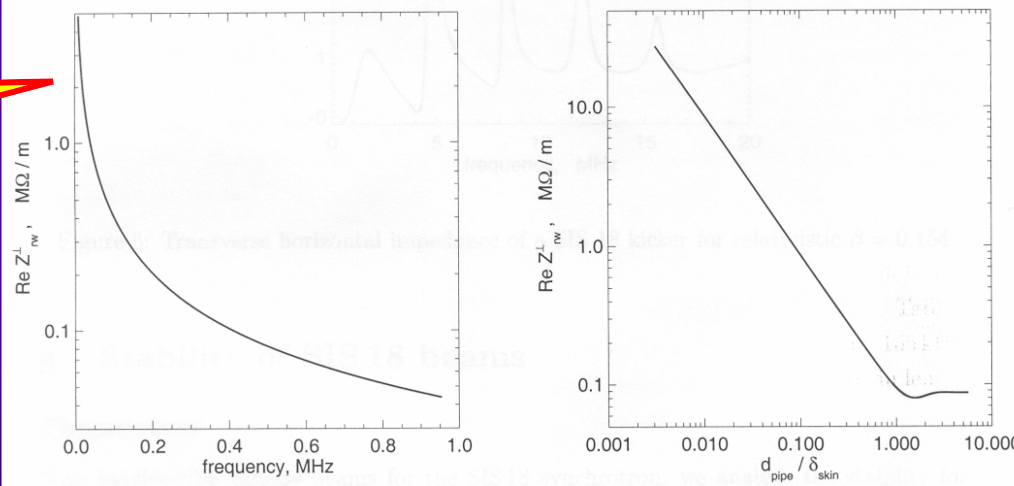

Figure 4: Transverse resistive wall impedance [Eq. (30)] as a function of the frequency (left) and of the wall thickness (right). Note the logarithmic scale for $Z^{\perp}_{\mathrm{rw}}$ and d_{pipe}.

is equal to $\delta_{\mathrm{skin}} = 0.3$ mm at the frequency 1.9 MHz, i.e. this is the thin-wall regime for such a pipe.

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