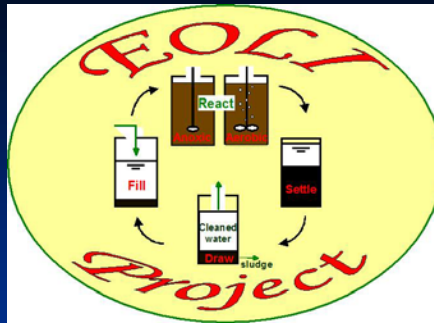
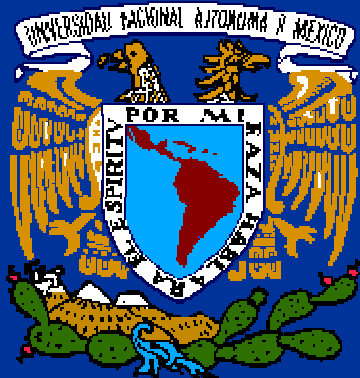




EOLI

Efficient Operation of Urban Wastewater Treatment Plants

Work Package 5



Control Design and Applications

Partner 6, UNAM

2nd annual Report



Contract Number ICA4-CT-2002-10012



Milan, Italy, Nov 22-24, 2004

WP5 Objective (UNAM)

Design and test of a (sub-)optimal control strategy for FedBatch bioreactors, treating Wastewater containing toxic or recalcitrant compounds, as described by EOLI Model 1 (EM1)

The Control Strategy have to be robust, reliable, easy to implement, adaptive and low-cost

WP5 status (UNAM)

Performed	Planned
1. Optimization Objectives (T_o+12)	
2. Control strategy Proposal (T_o+27)	
3a. Experimental Validation +shock load (lab scale) +comparison to FTC (lab scale) (T_o+30)	3b. Experimental Validation +Long Term stability (lab scale) (T_o+30) + Field scale ED-TOC test (T_o+36)
	D5.1 Control laws based on software sensors for optimizing the performance of SBRs (T_o+27)
4. Publications +2 National +5 International +2 International Submitted	D5.2 Report on full-scale performance of the optimal control law and the software sensors in terms of process and economic variables (T_o+30)

1. Optimization Objectives

- ❑ **Objective:** Minimization of the reaction time
- ❑ **Control variable:** input flow
- ❑ **Measured variables:** Dissolved oxygen concentration (DO), Volume
- ❑ **Hardware sensors required from WP3:** none
- ❑ **Expected benefits:** operation robustness; avoid the deacclimation of the biomass; higher efficiency; smaller physical dimensions of the reactor; reduction of off operation times; reduced costs of operation and installation

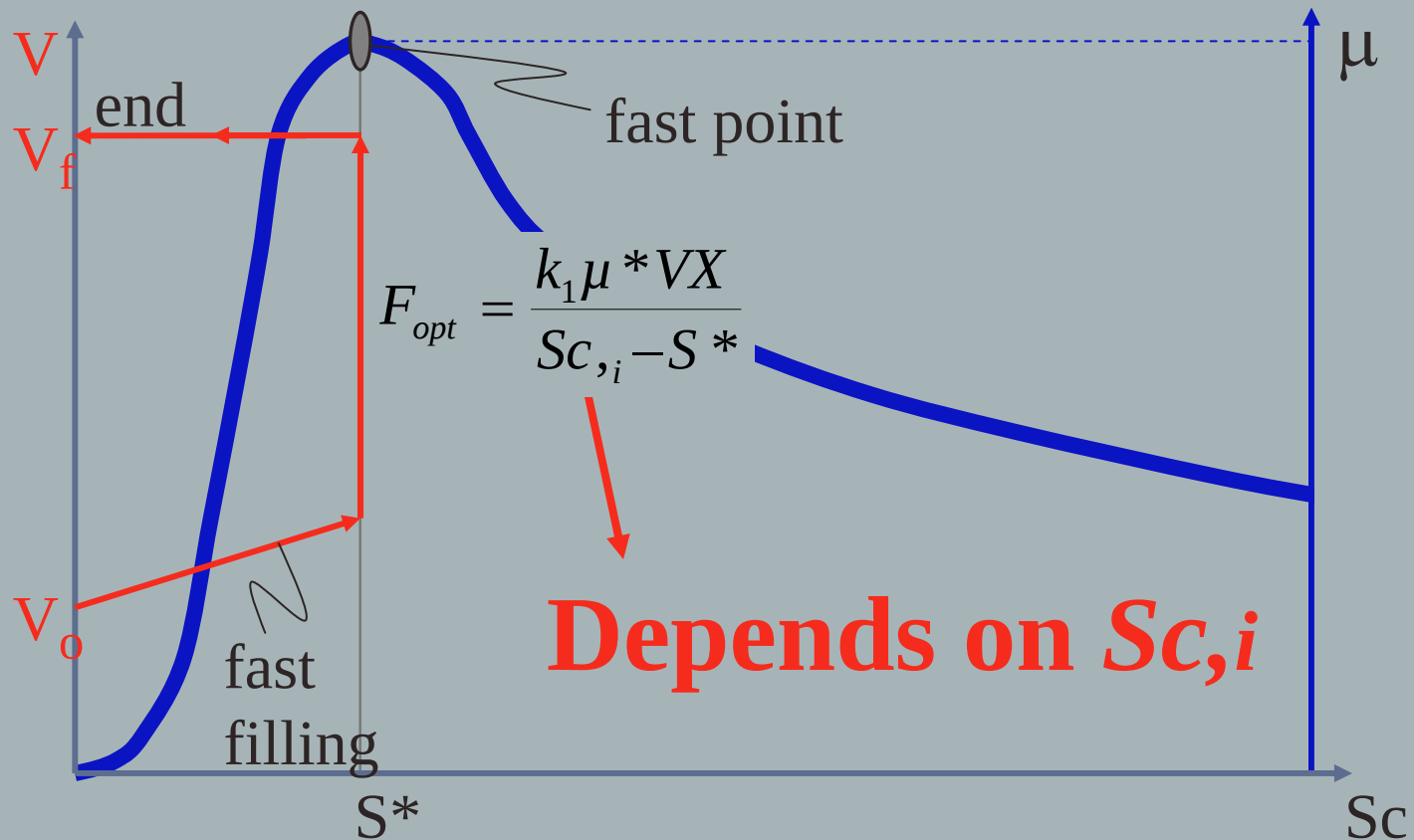
2. Control Strategy Proposal

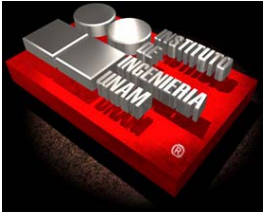


Event-Driven Time Optimal Control (EDTOC):

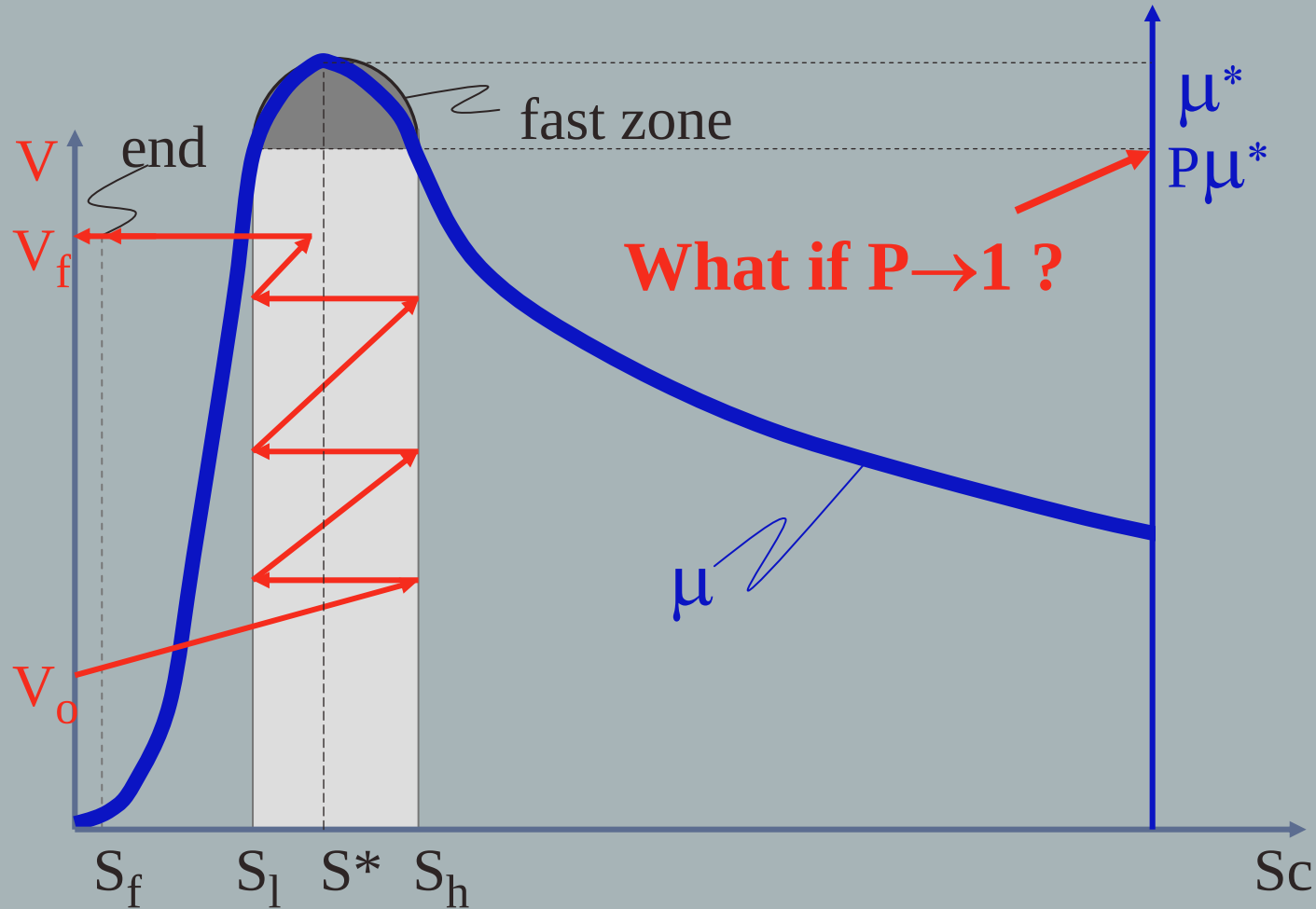
- **Robustness** : to shock loads (inflow's peak substrate concentrations)
to parameter uncertainties
to model structure uncertainty
to sensor errors and noise
- Time (sub)**optimality**
- Needs only easy and **cheap** to measure variables
- Uses **Software to Sense** events (not the whole state variable value)
important for control

Time Optimal Control (TOC)





Event Driven TOC





γ Formula for EDTOC

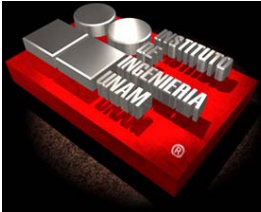
$$\dot{X} = \mu X - X \frac{q_{in}}{V}$$

$$\dot{S}_C = -k_1 \mu X + (S_{C,in} - S_C) \frac{q_{in}}{V}$$

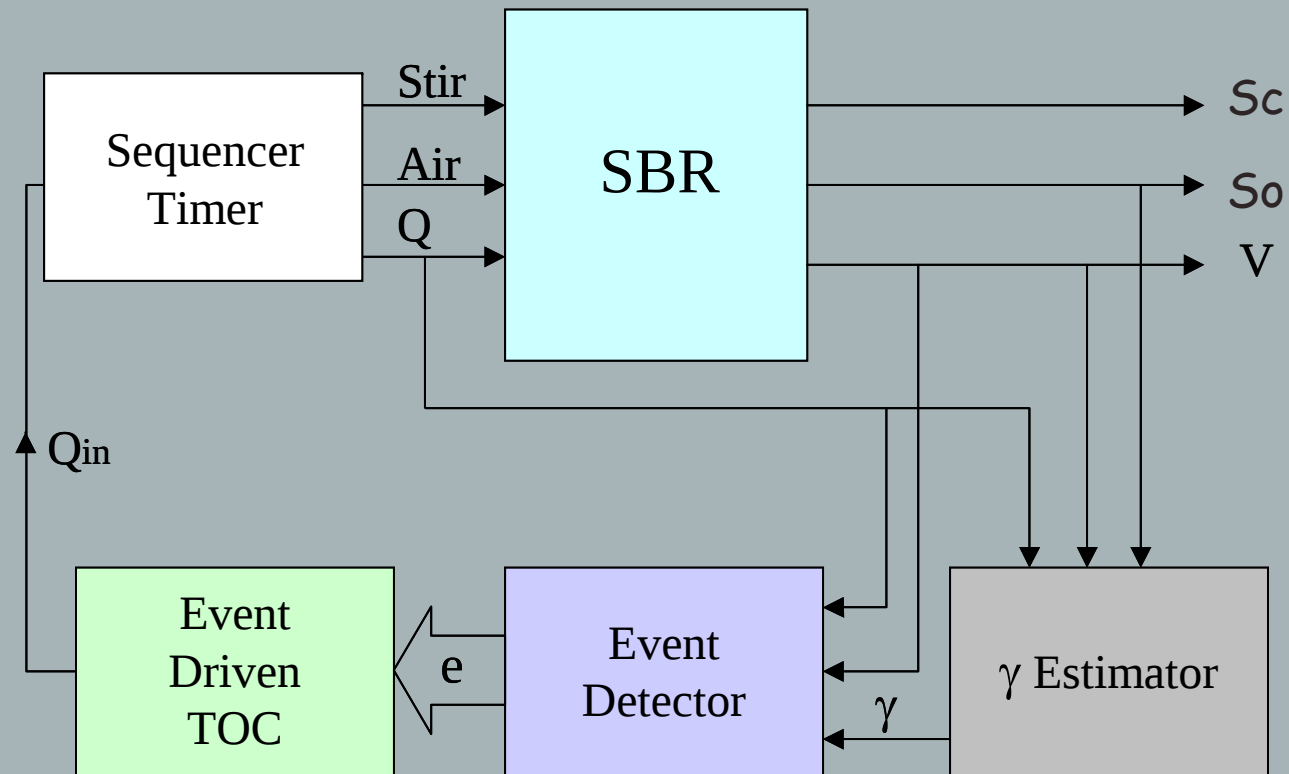
$$\dot{S}_O = -k_2 \mu X - bX + K_L a^* (S_{O_s} - S_O) + (S_{O,in} - S_O) \frac{q_{in}}{V}$$

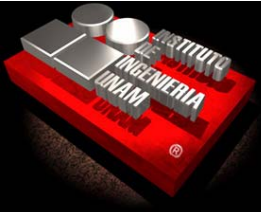
$$\dot{V} = q_{in}$$

$$\gamma^{\Delta} = (k_2 \mu + b) V X = K_L a (O_s - S_O) V - S_O q_{in} + V (dS_O / dt)$$

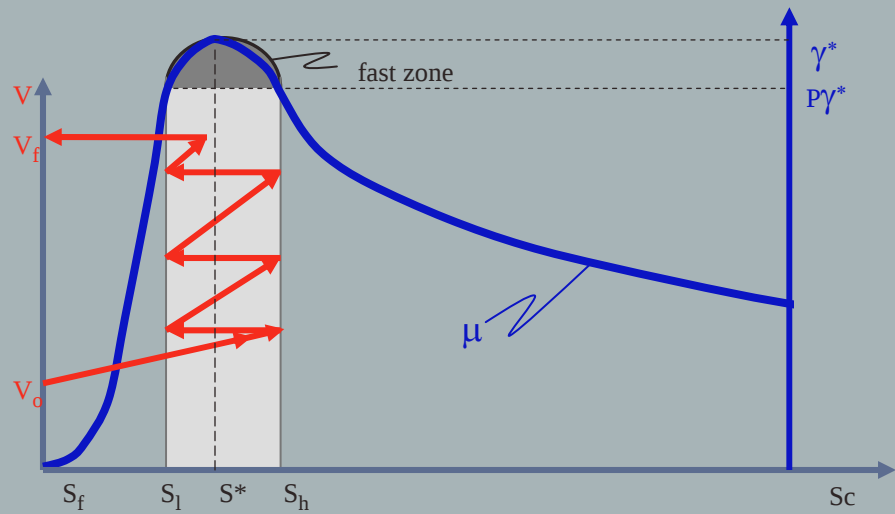


EDTOC: Event driven TOC



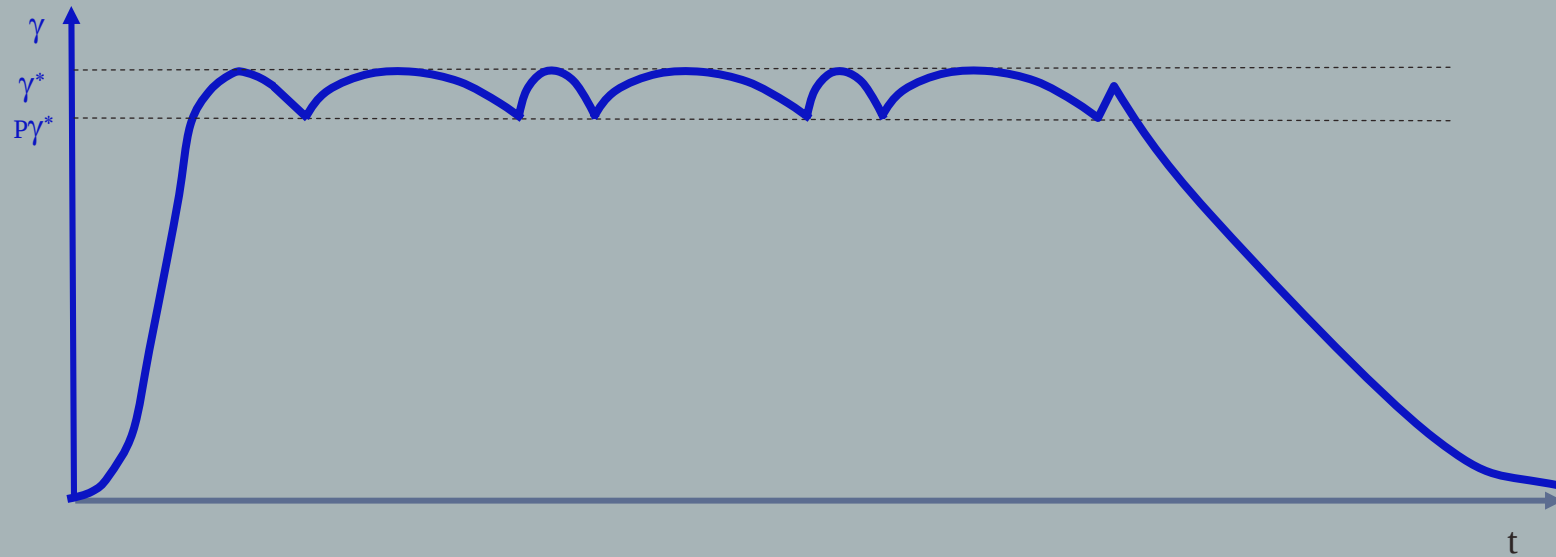


EDTOC



Robust

Measurement of μ, S not required



3^a. Experimental Validation (lab)



Software:

LabView

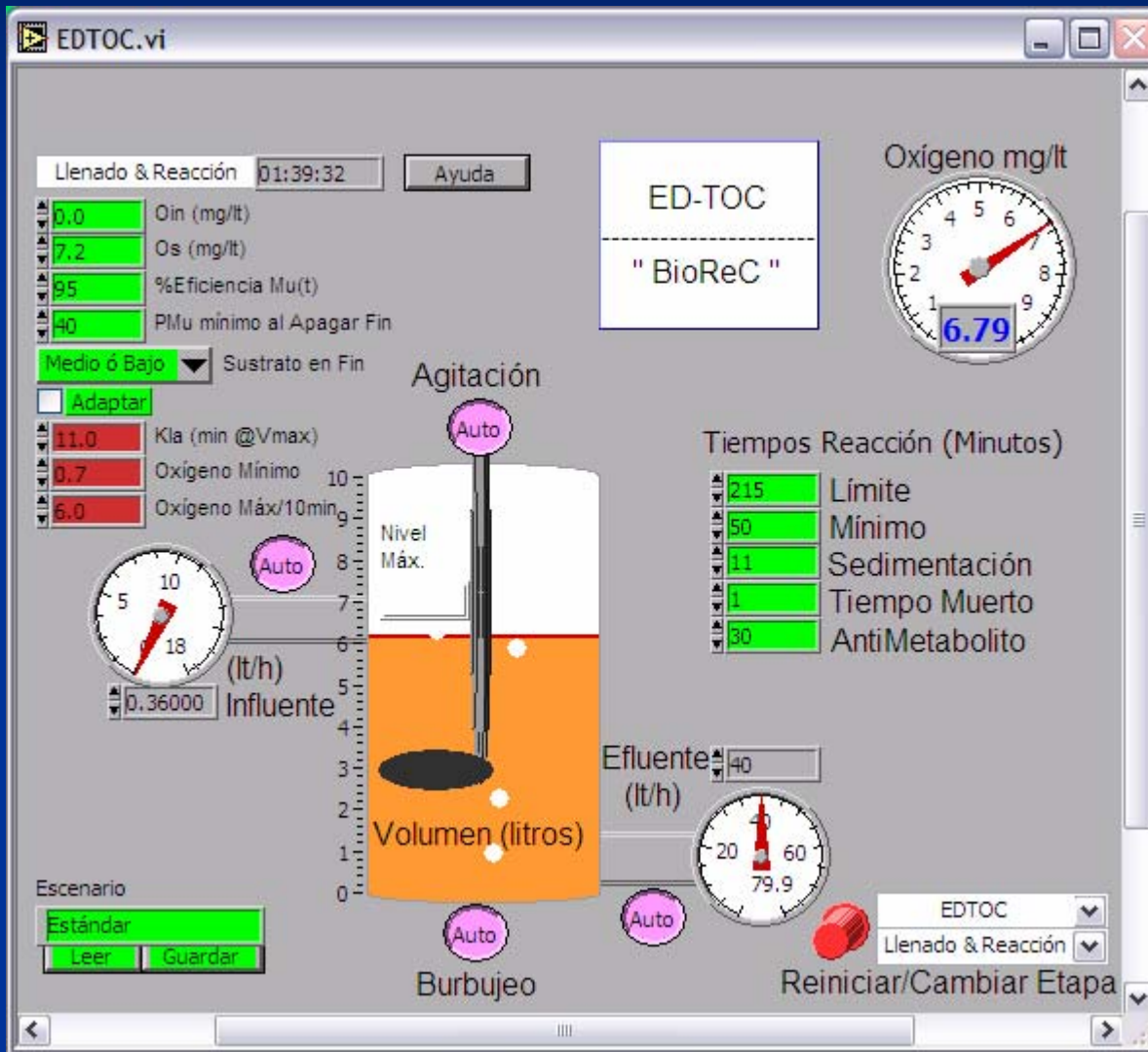
I/O Hardware:

(National Instruments)

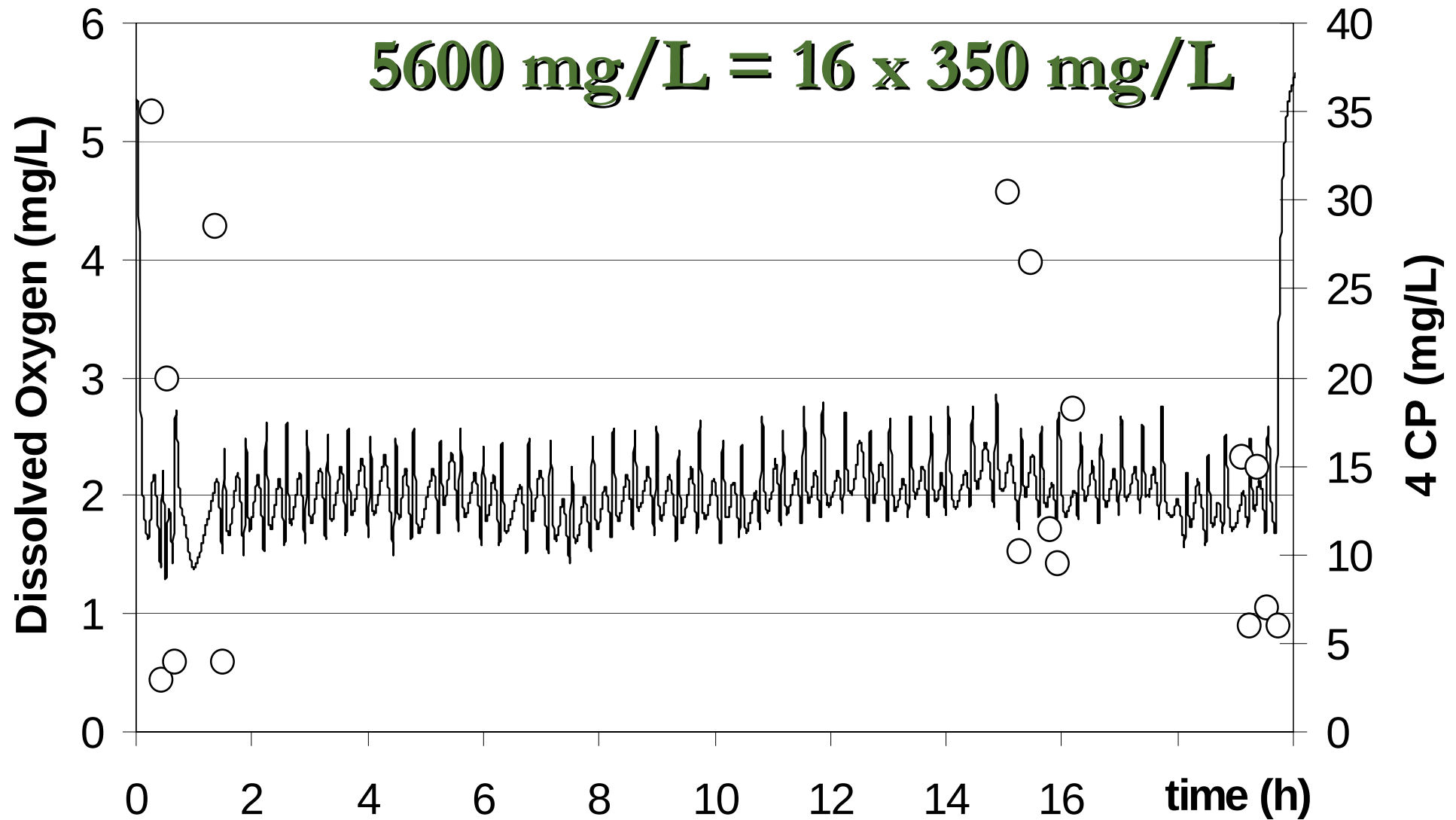
PC-card 6025E

Integration:

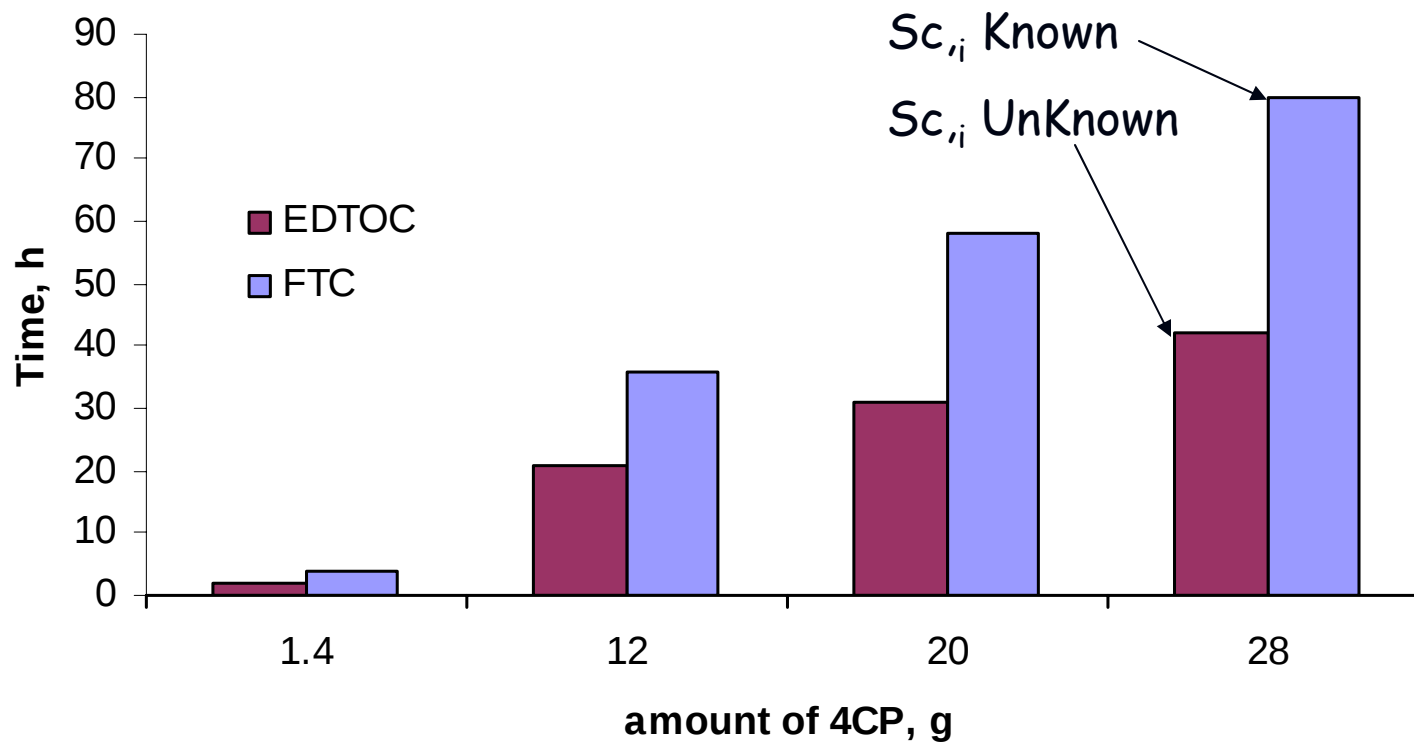
Not planned



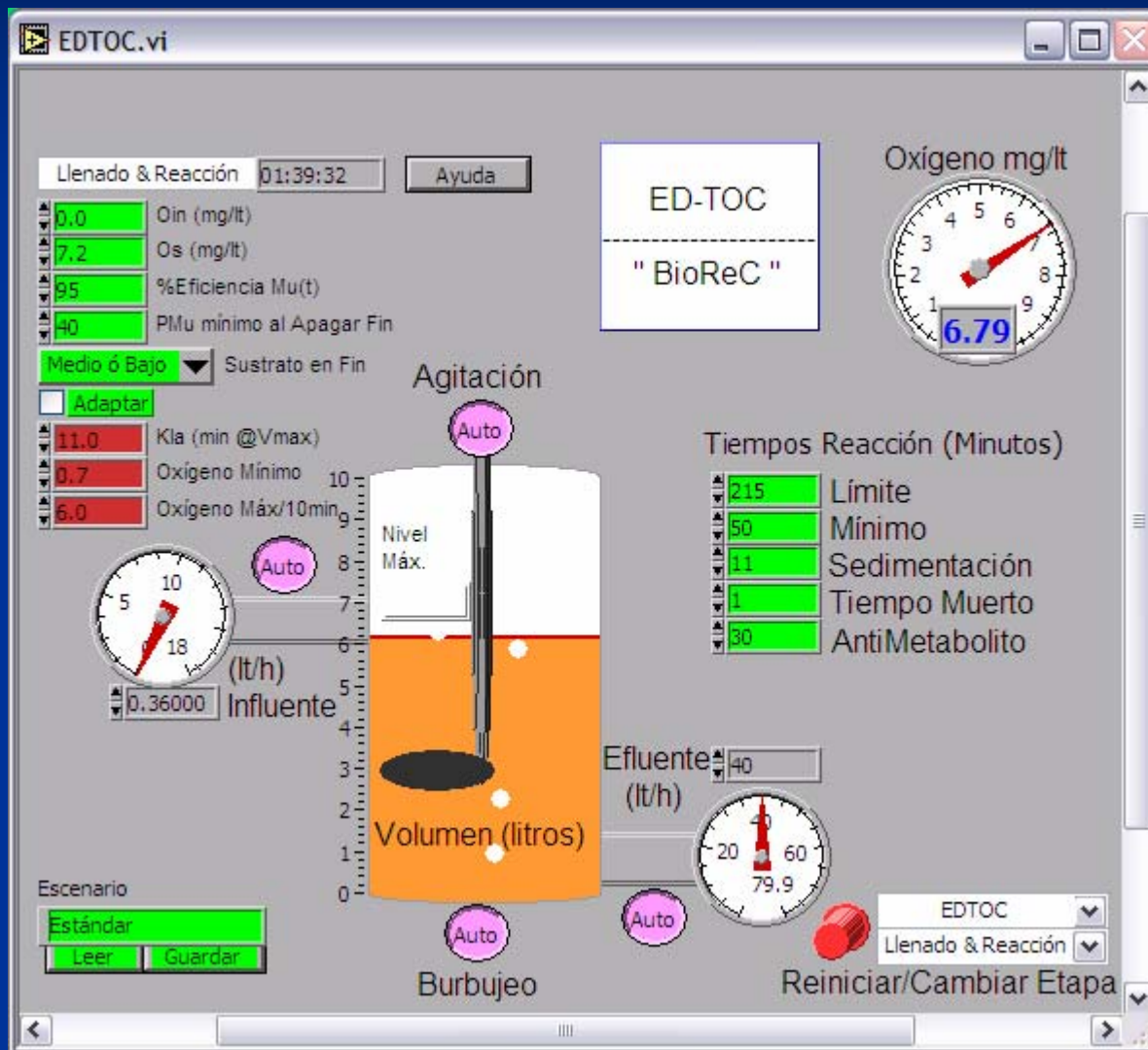
EDTOC ($S_{c,i} = 5600 \text{ mg 4CP/L}$)



*Comparison of the time necessary for degrading
the same quantity of 4CP by the
FTC and ED-TOC strategies*



3^b. Experimental Validation (Plan)



Software (Field scale):

LabView (scalable from lab)

OPC (OLE for Prc.Control)*

I/O Hardware (Field scale):

(Beckhoff)

BK9000 I/O bus*

Integration (Field scale):

Allowed, easy,

*Modbus (Open Standard)

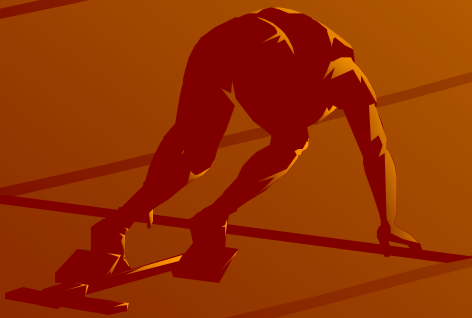
4. Publications

1. Betancur, M.J.; Moreno, J.A. and **Buitrón, G.** (2004). Event-driven control for treating toxicants in aerobic sequencing batch bioreactors. *Proc. CAB9*, Nancy, France.
2. Betancur, M.J.; Moreno J.A. and **Buitrón, G.** (2004). Practical Optimal Control For Fed-Batch Bioreactors. *Preprts of NOLCOS 2004*, pp 1517-1522, Stuttgart, Germany
3. Betancur, M.J; Titica, M; Moreno, J.A.; **Dochain, D.** and Guay, M. (2004). Event Software Sensor and Adaptive Extremum Seeking alternatives for optimizing a class of fed-batch bioreactors. *Proc. of DYCOPS 2004*, Cambridge, Massachusetts, USA
4. **Buitrón, G.**; Moreno, J. A.; Betancur, M. J. and **Moreno, I.** (2004). Aerobic treatment of toxic wastewater: problems, solutions, and open questions. *Proceedings of the 3rd IWA Specialised Conference on Sequencing Batch Reactor Technology-SBR3*, February 2004, Noosa, Australy
5. **Buitrón, G.**; **Moreno-Andrade, I.**; Betancur, M.J. and Moreno, J.A. (2004). Application of the event-driven time optimal control strategy for the degradation of inhibitory wastewater in a discontinuous bioreactor. *Proc. 4th World Water Congress, IWA*. 09/2004. Marrakech, Morocco
6. **Buitrón, G.**; **Moreno-Andrade, I.**; Betancur, M.J. and Moreno, J.A. (2004). Biodegradación de efluentes altamente contaminados por compuestos fenólicos utilizando una estrategia de control óptima, in Spanish. *Memorias del XIV Congreso de Ingeniería Ambiental y Ciencias Ambientales*. 12-14/05/2004, Mazatlán, México.
7. Betancur, M.J.; Moreno, J.A.; **Buitrón, G.** and Moreno-Andrade, I. Control y mejoras en biorreactores para tratar aguas residuales tóxicas, in Spanish. *Proceedings of the Congreso Anual de la AMCA*. October 2004, D.F., México, pp. 490-495.
8. Moreno, J. and **Dochain, D.** Global observability and detectability analysis of uncertain reaction systems. *Subm to the 10th. IFAC World Congress*. Prag, July 2005.
9. Betancur, M.J.; Moreno, J.A.; **Moreno-Andrade, I.** and **Buitrón, G.** Control strategies for treating toxic wastewater using bioreactors. *Submitted to the 10th. IFAC World Congress*. Prag. July 2005.

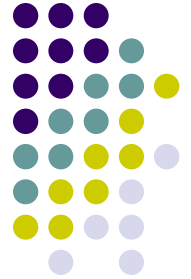
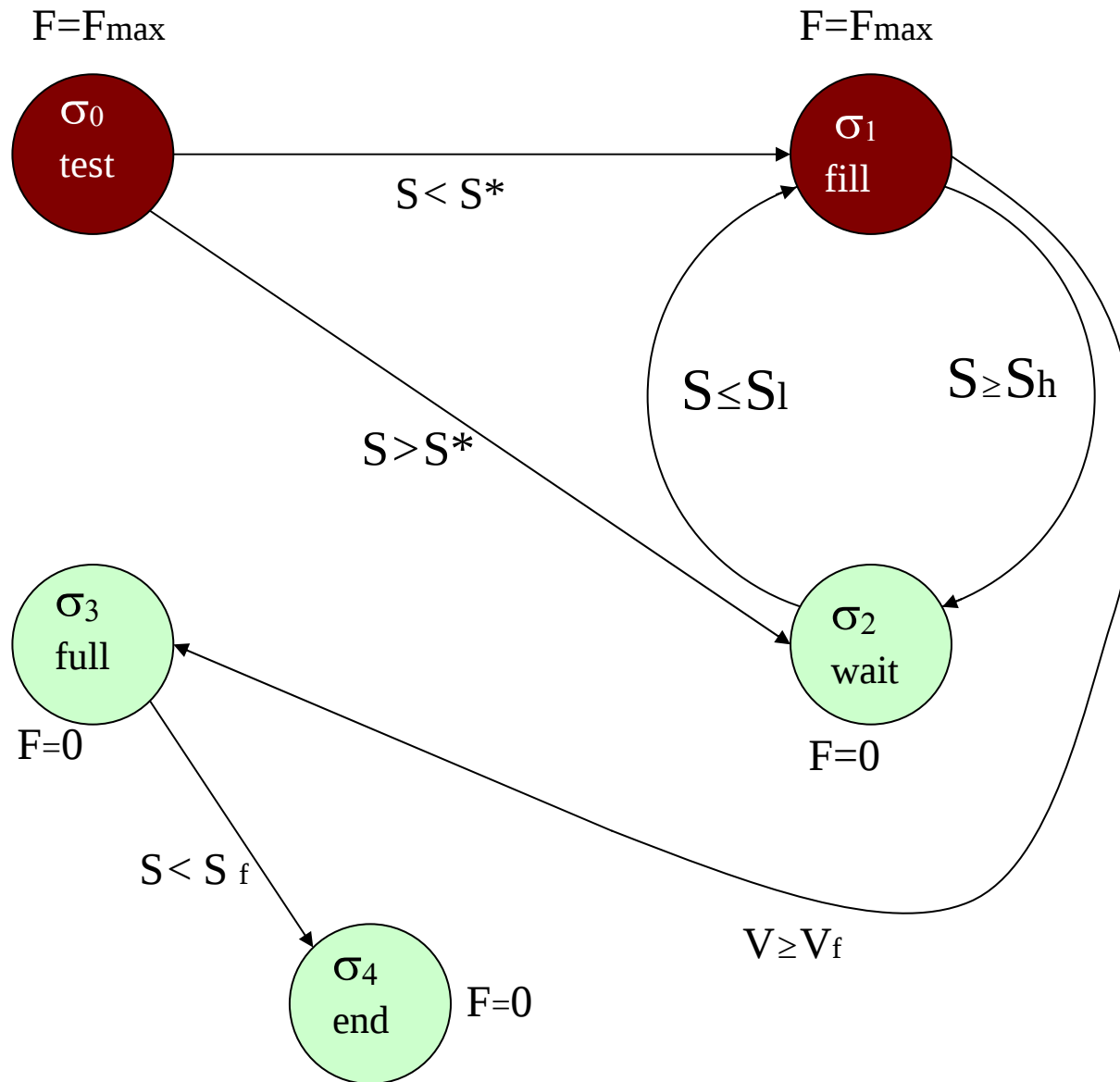
Conclusions (WP5 UNAM)

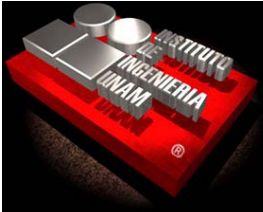
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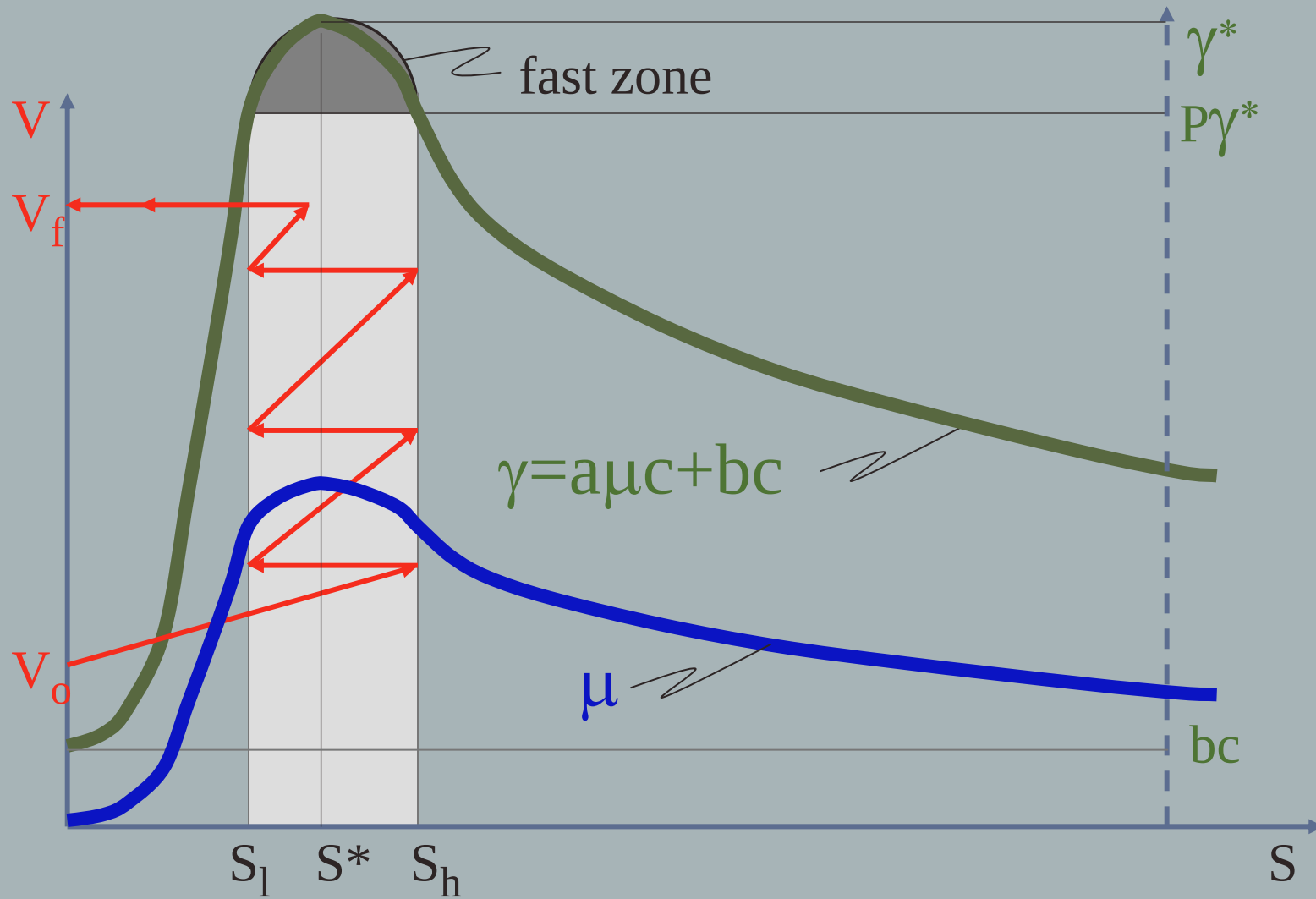


EDTOC states





γ EDTOC



EDTOC Zoom of 2 fill-wait cycles

