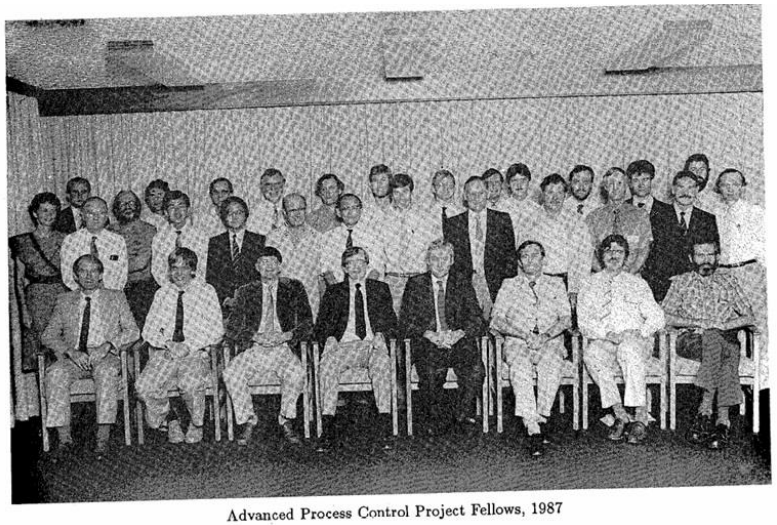
Bob@ANU: Bridging the Theory/Practice Gap

Sam Crisafulli (7 of 34)

Warren Centre Study – Benefits from Advanced Control

Published in the Journal of Process Control, 1991

- Advanced Control applied to process industries can deliver financial benefit ranging from 2-6% of operating costs
- Theory/Practice Gap main impediment to realizing the benefits



Advanced Process Control Project Fellows, 1987

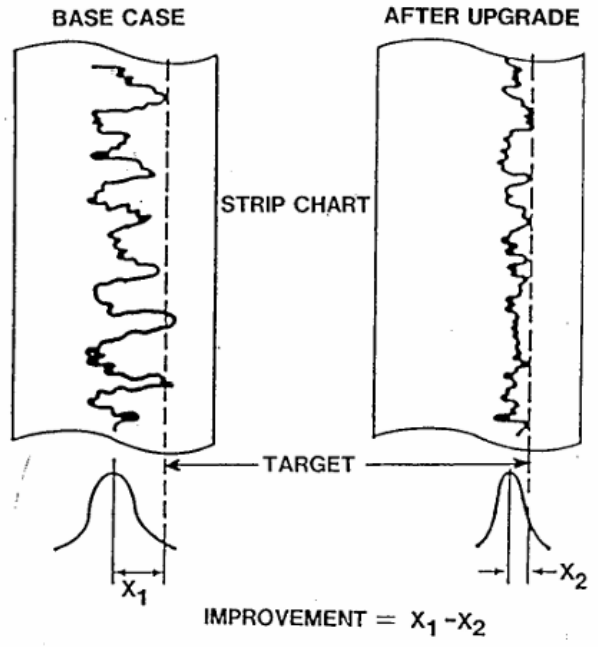


Figure 5: Typical control upgrade improvement

Benefits from process control: results of a joint industry–university study

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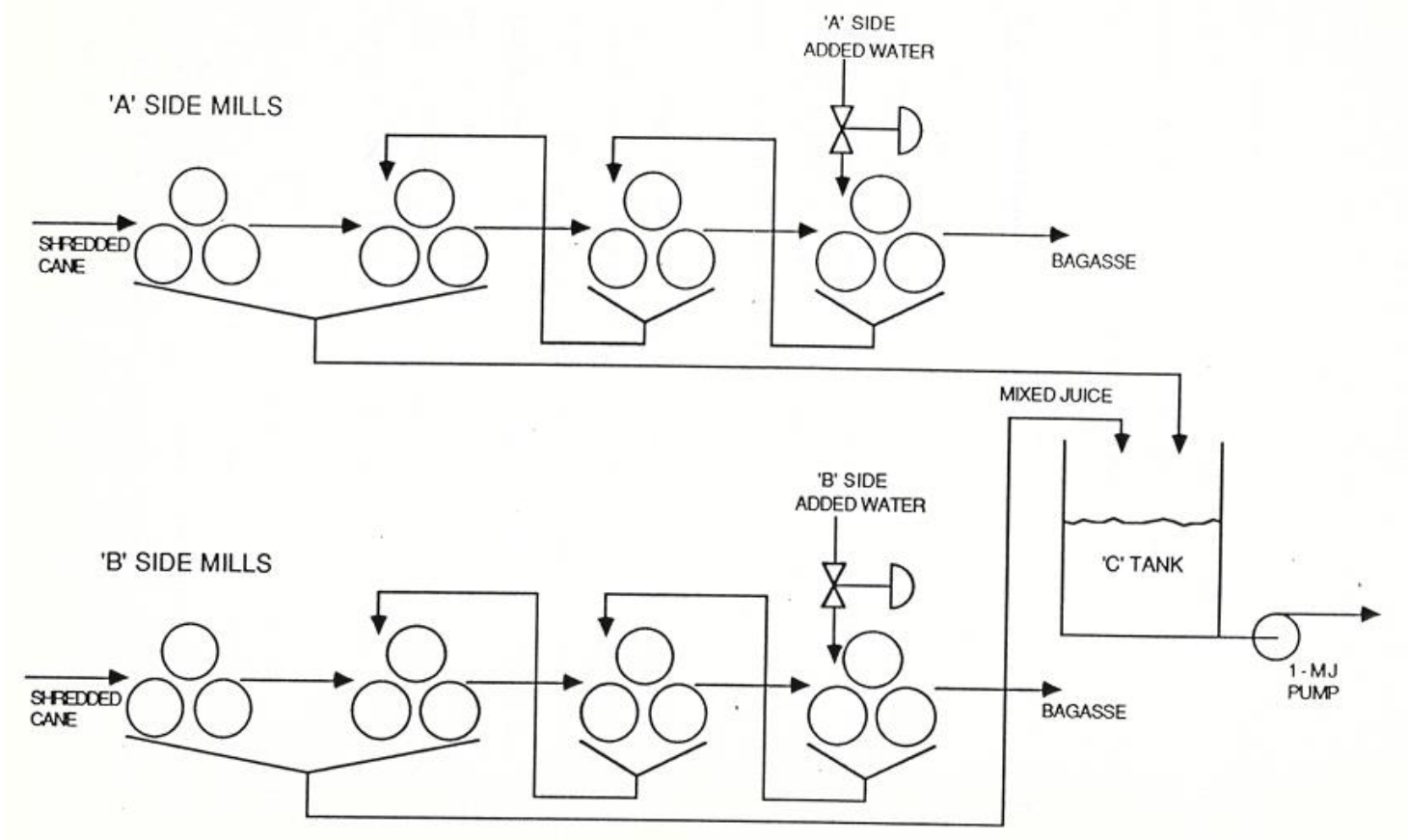
A key component of any process control upgrade project is the initial benefits analysis. This analysis defines the correct scope of the project based on the plant's economics, production requirements and capacity, and equipment capacity. The scope must be defined to correctly determine the process units and controls included in the project, design the control strategies, specify the equipment required, plan the engineering aspects and develop a realistic schedule. As a result of the importance of this topic, a major study was undertaken by the Warren Centre for Advanced Engineering (University of Sydney) to establish a general method to be made available to Australian industry. The study was performed by a team of over 40 professionals from industry, government and academe and lasted over 1 year. The resulting method for control benefits analysis is described in this paper. The method addresses the organizational aspects of personnel interviews and data collection. It also addresses technical issues such as the calculations and plant tests required to predict control benefits. None of this material is new in itself, but the selection and integration provides a coherent method not available elsewhere. In addition to the method, this paper describes seven industrial case studies. Substantial benefits, ranging from 1.4 to 6% of operating costs, were identified in the case studies. The success of these studies indicates that the benefits method can be adapted to a wide range of processing plants.

Buoyed by this business-backed assessment, Bob was sought by Australian Industry to take them to the promised land (1991)

- One of the early companies to engage Bob was CSR Sugar (now called Wilmar)
- Raw sugar factories are good candidates for advanced control
- High capital and operating costs
- Complex control problems nonlinear, time-varying dynamics, multi-variable, etc, etc



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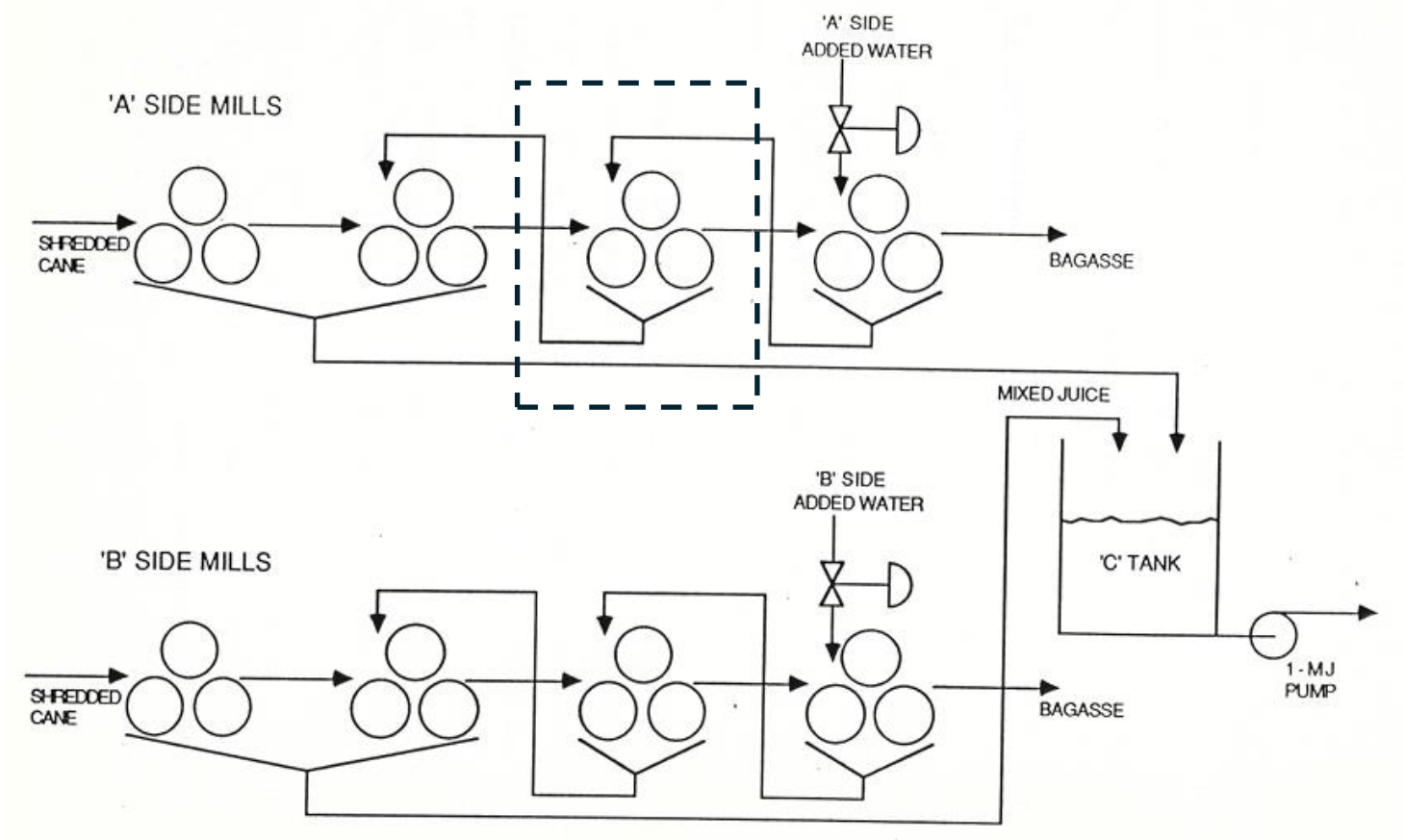
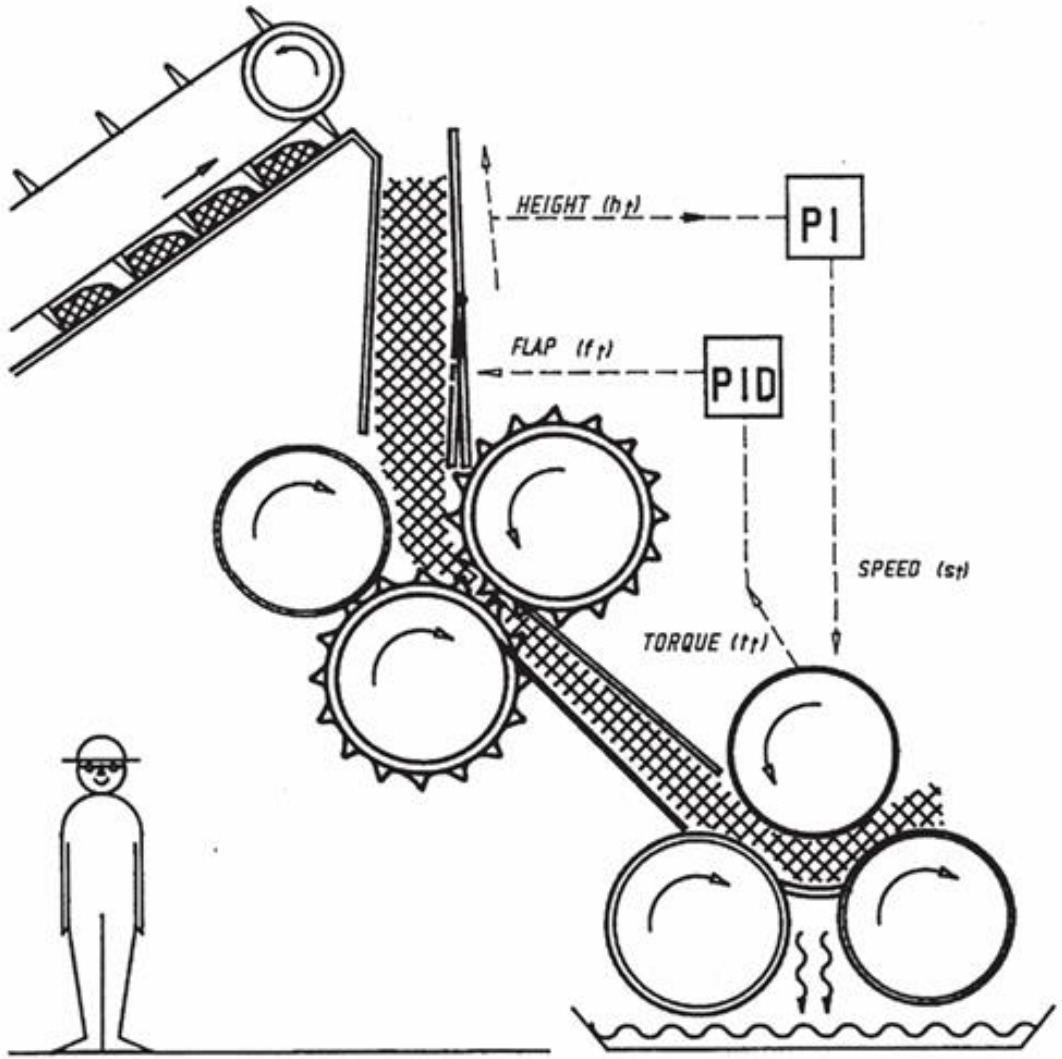


The sugar mill proper



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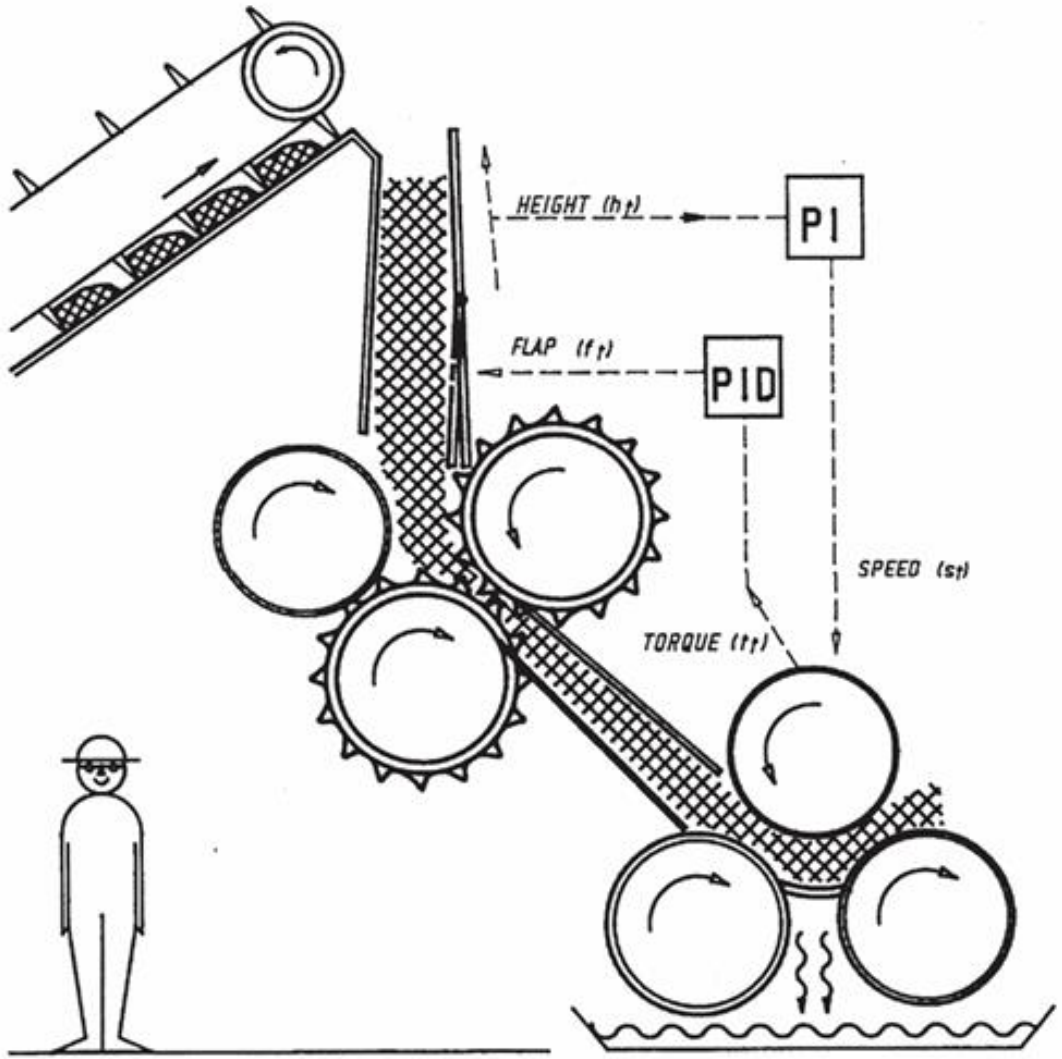

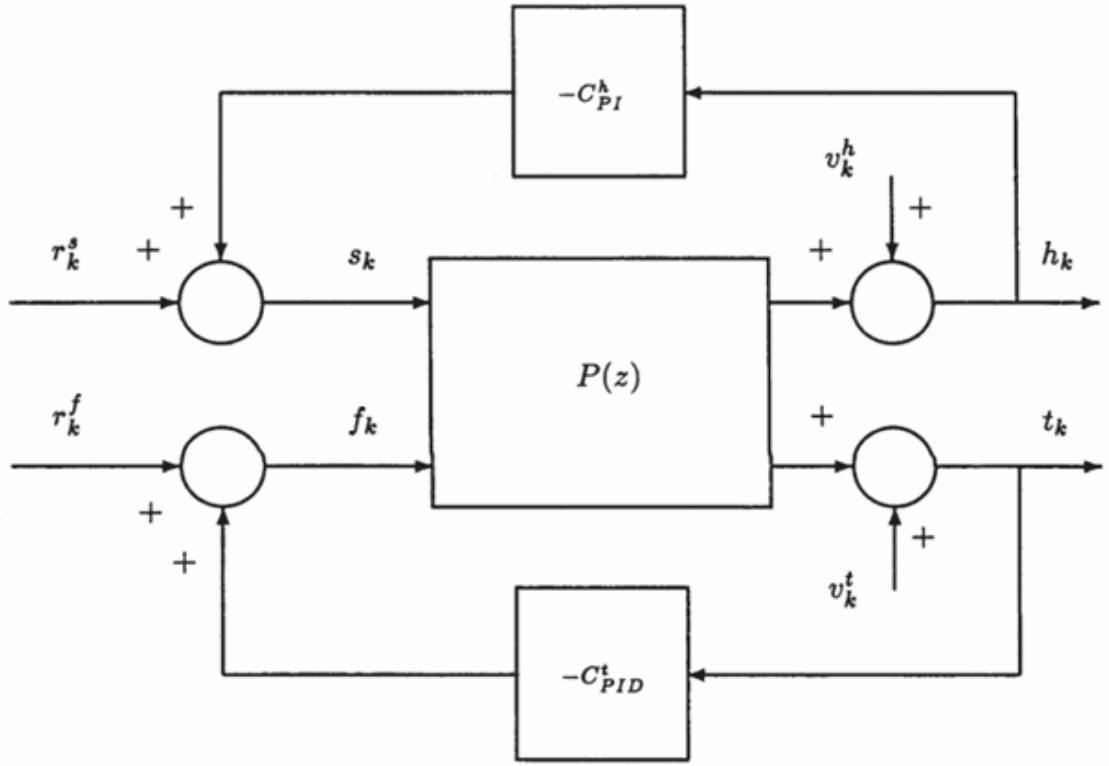

- f = Flap Position
- t = Torque
- s = Mill Speed
- h = chute height

Control objective

- Maximum extraction ➔ maximize torque ➔ maximize chute height
  - Subject to: a) do not overfill chute and b) do not run chute empty
- How much torque? Up to 1.2 MNm
- What does 1.2 MNm mean?

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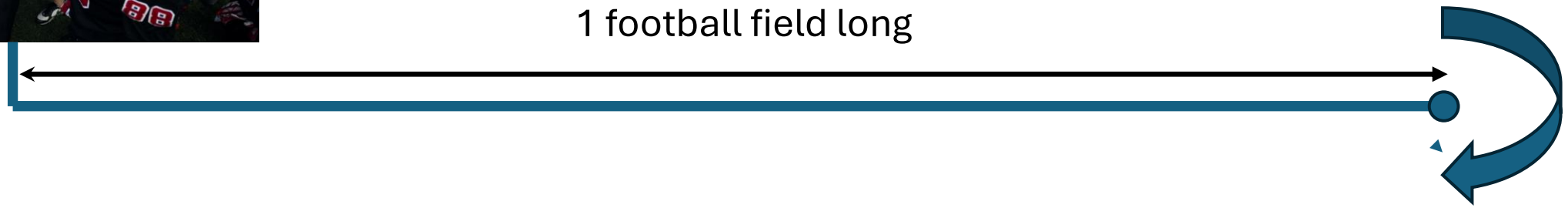
1 football team

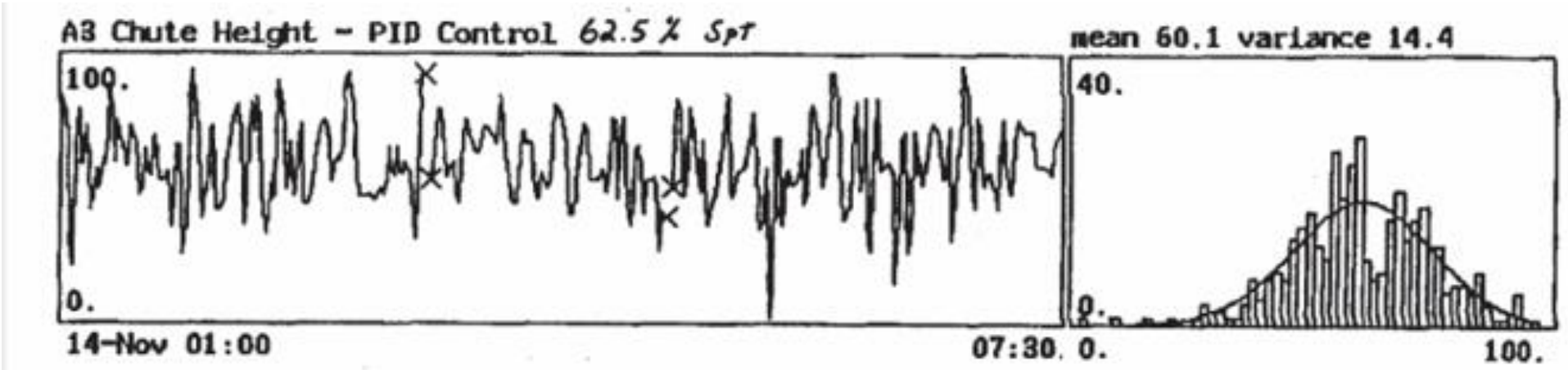
1.2 MNm torque needed
to lift the team

1 football field long



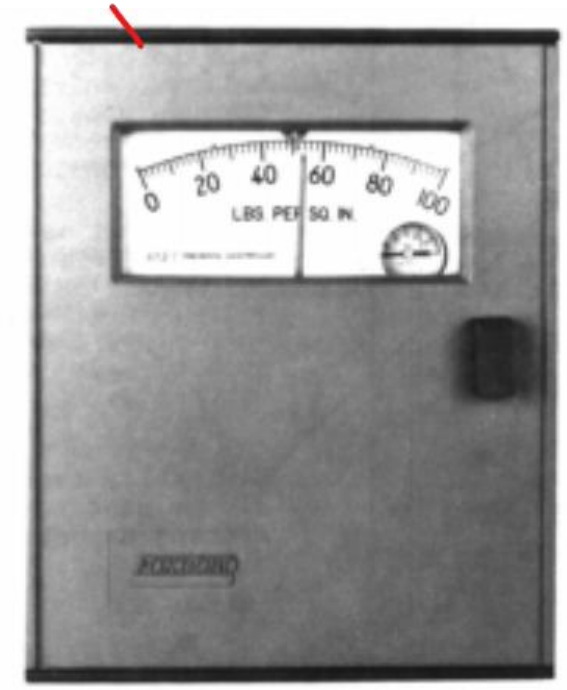
Control objective and solution

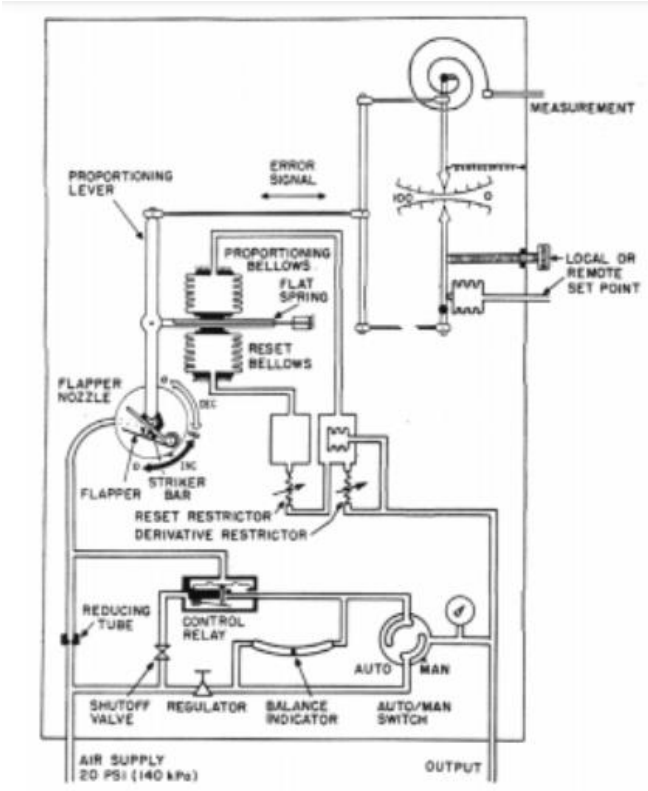
- Maximum extraction ➔ maximize torque ➔ maximize chute height
  - Subject to: a) do not overfill chute and b) do not run chute empty
- Solution: minimize chute height variance so that average height can be increased without violating the “do not overfill chute” constraint
  - **Note: Overfilling chute ➔ Angry operator due to having to clean up mess with a pitch fork**



Sam @ Sugar Mill

- Instrument Technician apprentice 1981 – 1984
- Installed and tuned Foxboro Model 40 pneumatic controllers
- Main requirement – ensure controller can withstand a punch by an operator (not bandwidth, settling time, gain/phase margin!)
- Later replaced by Bailey digital distributed control system





Advanced control solution:
Closed loop SysID, LQG, MISO, Iterative ID/Control Design

$$\begin{pmatrix} h_k \\ t_k \end{pmatrix} = \begin{pmatrix} P_{hs} & P_{hf} \\ P_{ts} & P_{tf} \end{pmatrix} \begin{pmatrix} s_k \\ f_k \end{pmatrix} + \begin{pmatrix} v_k^h \\ v_k^t \end{pmatrix}$$

- Success!
- Chute height variance reduced
- Average height increased without violating constraints
- But .....

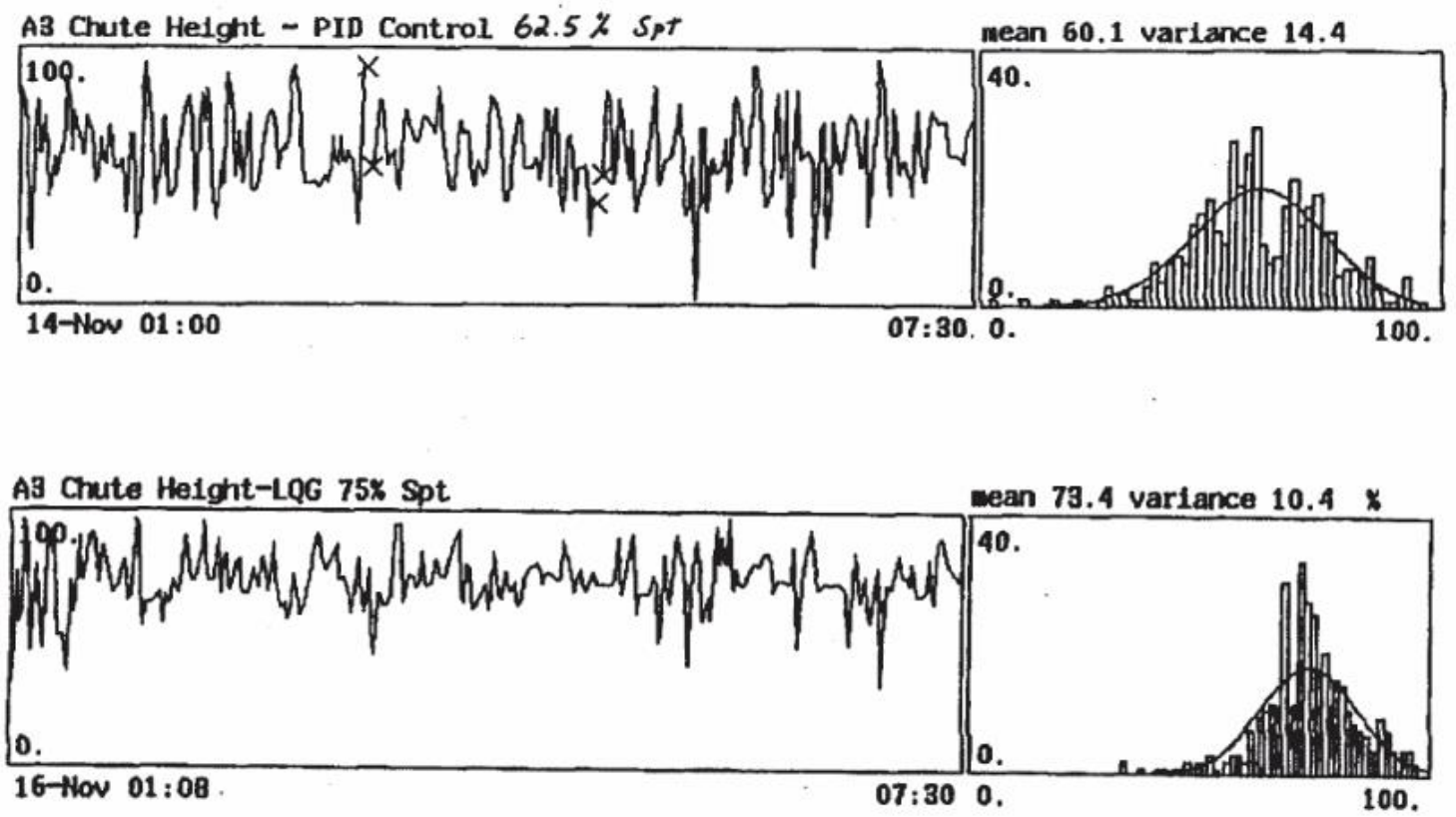
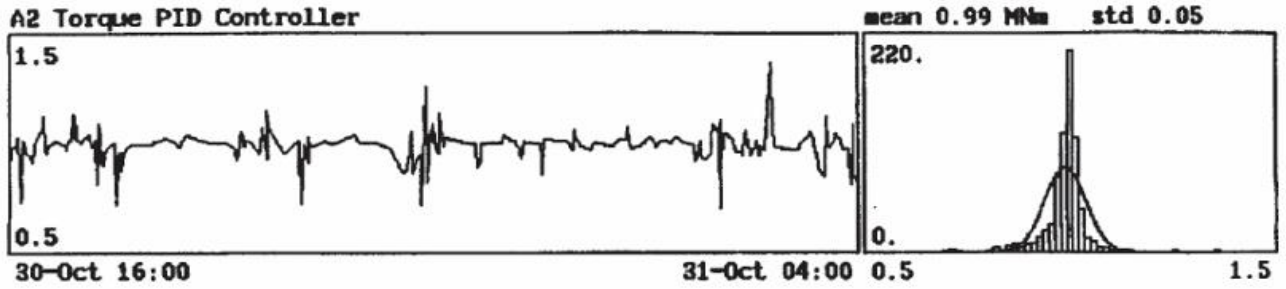


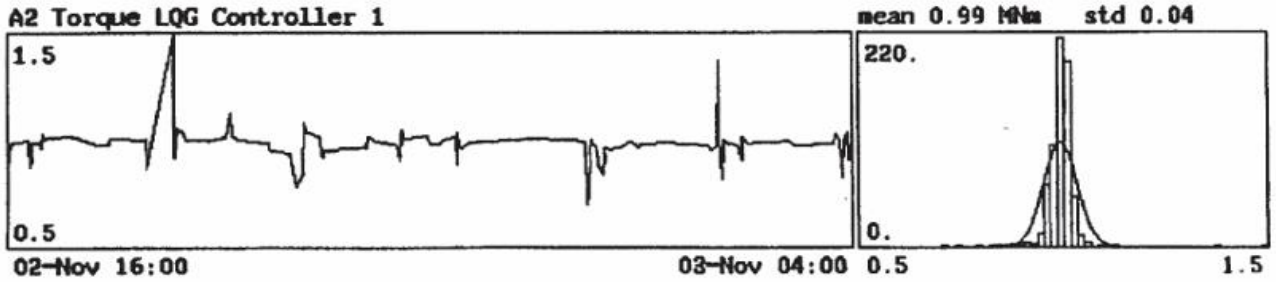
Figure 8.1: PID versus LQG chute height control - A3 Mill.

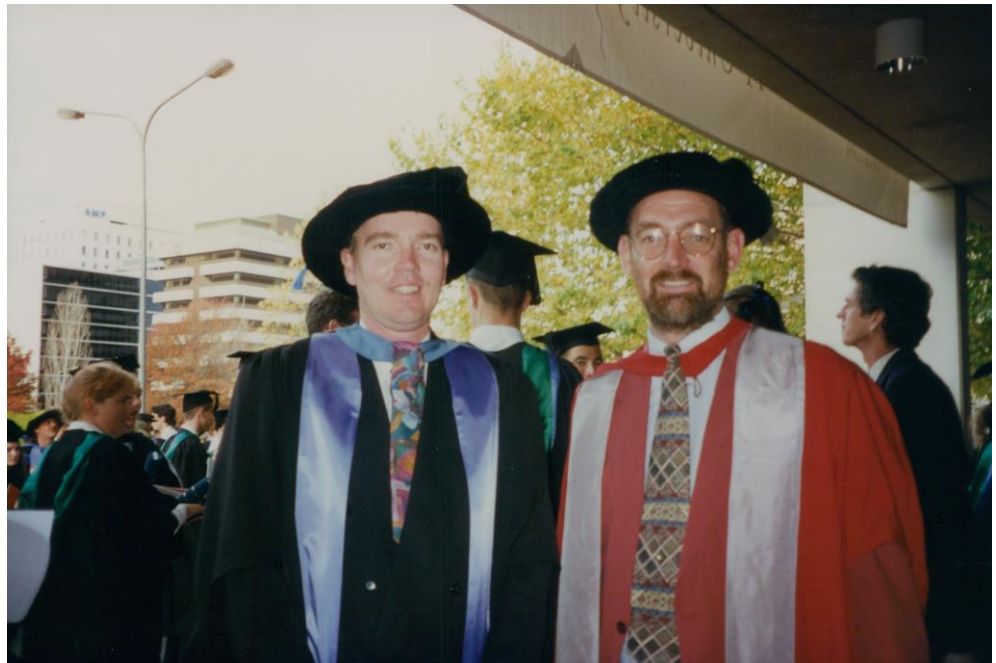
Advanced control solution:
The reality of real-world applications

Although, the LQG controller permitted the operation of the crushing mills with higher chute height levels, a corresponding improvement in the torque did not eventuate. This is due to the multi-variable nature of the process.

Ari Partanen, ANU PhD Thesis, 1995







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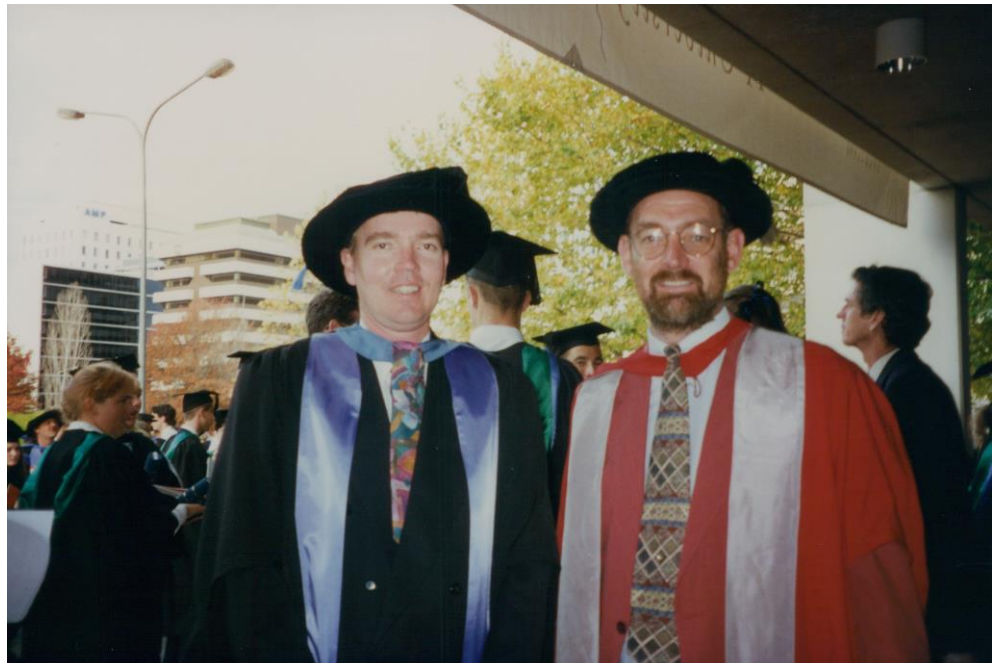
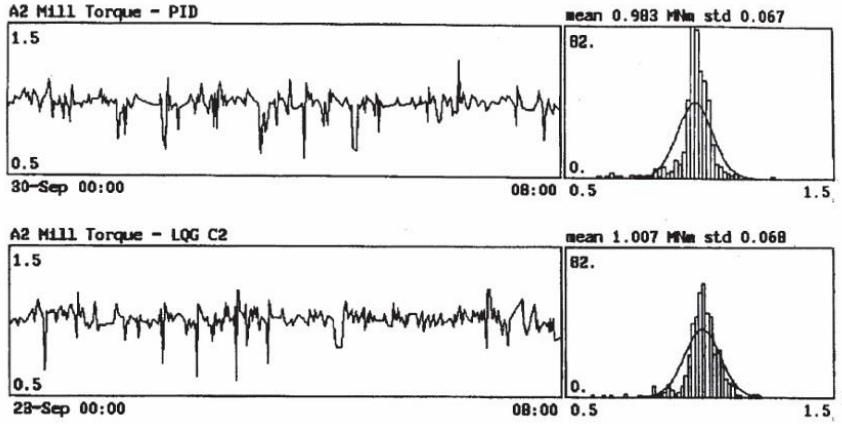
~~**maximize torque ➔ maximize chute height**~~



Early revelation for Bob

- Industry problems are as hard to define as they are to solve – don't accept industry problem statement as given
- Take the time to really understand the problem. Perhaps the solution isn't modelling/control/signal processing/etc
- This mindset instilled in his students
  - 10 of Bob's student's work at ASML
  - Sugar mill problem explained to me!

- Work on sugar mill problem continued which ultimately led to successful outcomes
- Many more Industry applications undertaken as part of the Research Centre



The Crazies!

- Bob was Director of the Industry/University Co-operative Research Centre for Robust and Adaptive Systems, 1991 – 1998
  - $(CR)^2ASys$ ➔ CRASys ➔ Crazies
- Four main partners: ANU, CSIRO, DSTO, BHP
- Many successful industry applications completed during this time

Examples of industry applications undertaken by CRASys

- Sugar Mills
  - Torque maximization of rolling mill for maximum sugar extraction
  - Cane fibre rate estimation
  - Vacuum pan recirculation rate estimation
  - Sugar dryer modelling for moisture control
- Steel Mills
  - Steel reheat furnace modelling and control
  - Steel roughing mill temperature estimation
  - Steel hot strip mill bearing condition monitoring
- Blackhawk helicopter vibration control
- Many others .....

Bob!

- An amazing career over 40 years
  - Researcher, teacher, mentor, academic, author, administrator and practitioner
  - (Australian) football player/referee, beer maker, bread maker, ….
  - All around good bloke

- Thank you and good luck