Analyzing Control Problems and Improving Control Loop Performance
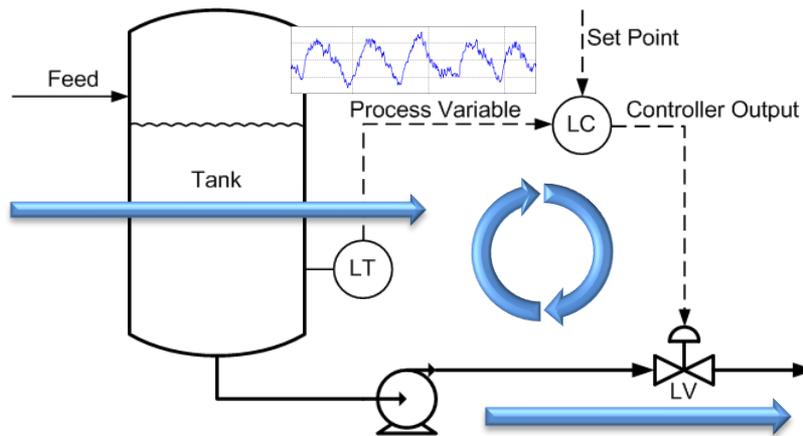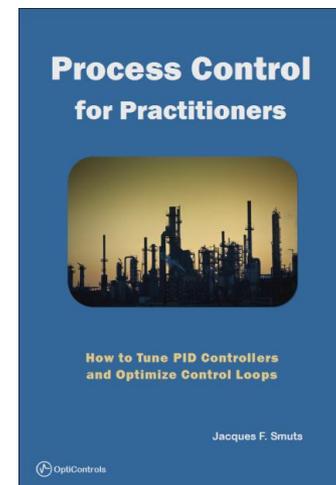
-by Jacques F. Smuts
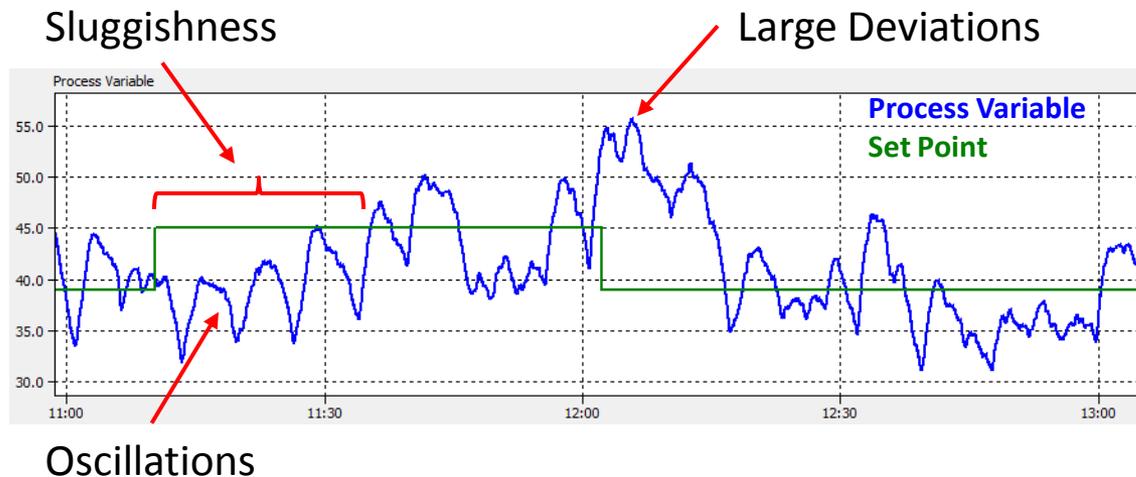

CHEM|NNOVATIONS
2011 | CONFERENCE & EXPO

Presenter

- Principal Consultant at OptiControls Inc.
  - League City, TX
- 20 years experience in process control
  - Loop optimization and troubleshooting
  - Consulting and control strategy design
  - Process control training
- Senior member of ISA, P.E., Ph.D.
- Author of the book:
  "Process Control for Practitioners"
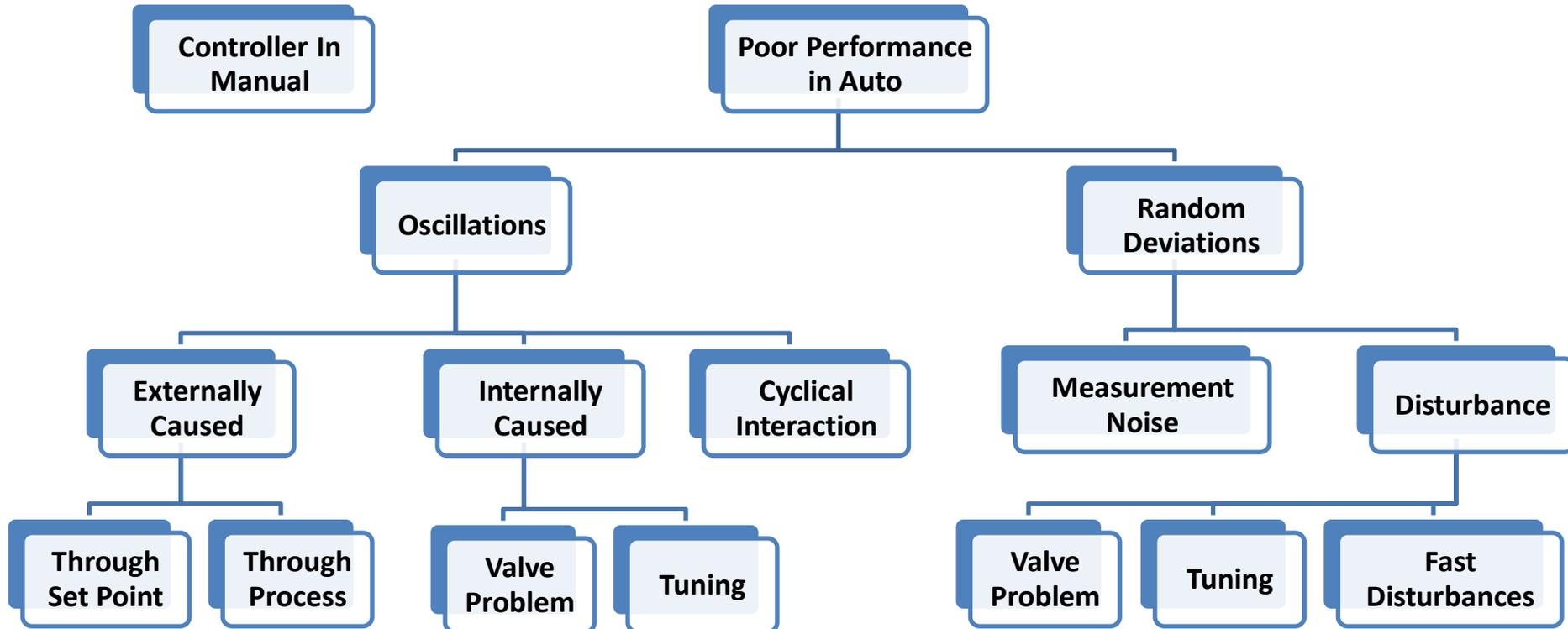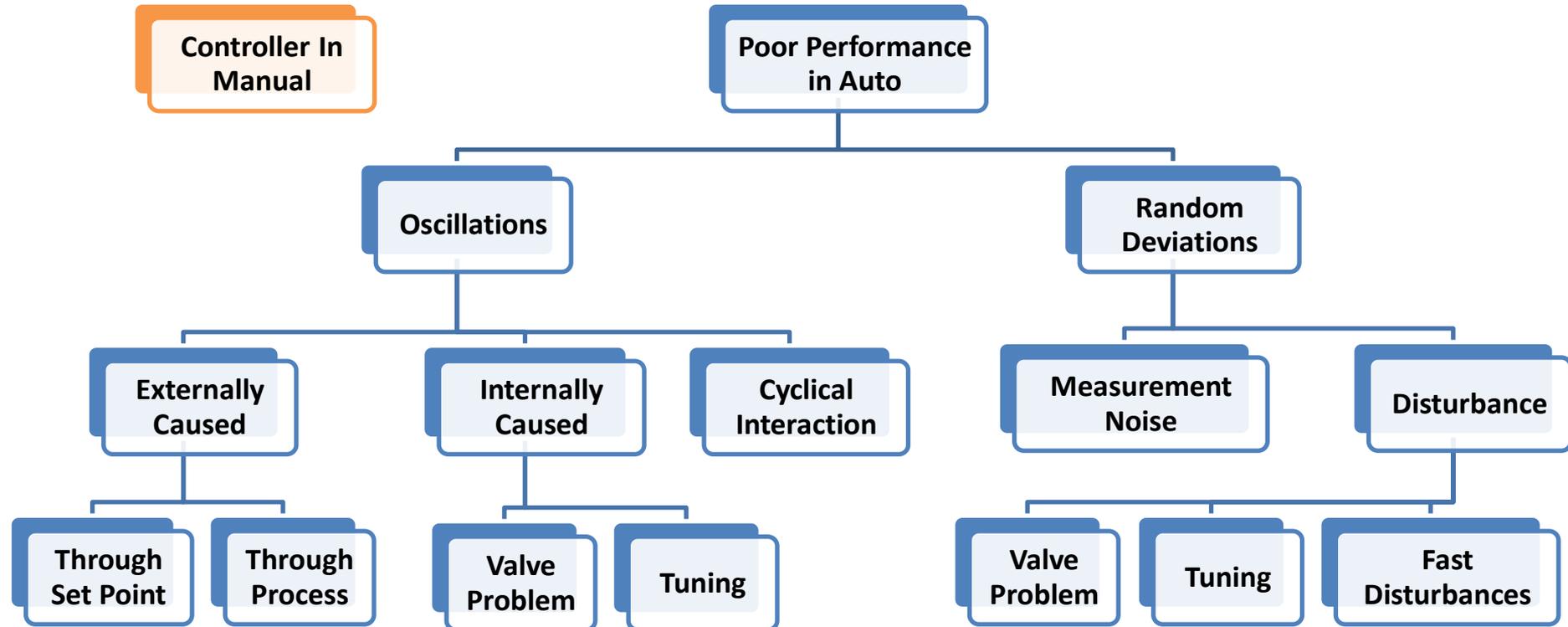
Poor Loop Performance

▶ Loop is in manual

▶ Poor performance in auto

– Loop oscillates or goes unstable

– Sluggish and/or large deviations from set point

▶ Often not tuning related

Sluggishness

Large Deviations

Oscillations

Problem Analysis

```
Controller In Manual

Poor Performance in Auto
├── Oscillations
│   ├── Externally Caused
│   │   ├── Through Set Point
│   │   └── Through Process
│   ├── Internally Caused
│   │   ├── Valve Problem
│   │   └── Tuning
│   └── Cyclical Interaction
└── Random Deviations
    ├── Measurement Noise
    └── Disturbance
        ├── Valve Problem
        ├── Tuning
        └── Fast Disturbances
```
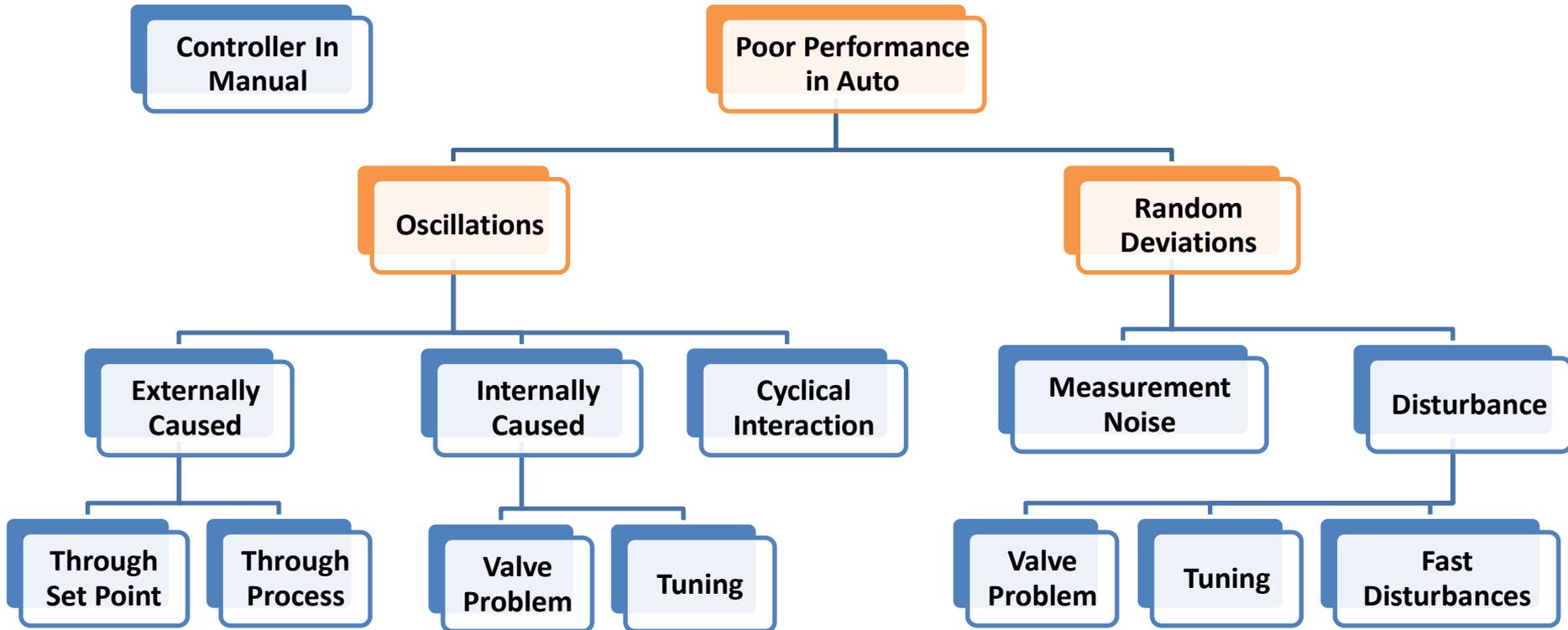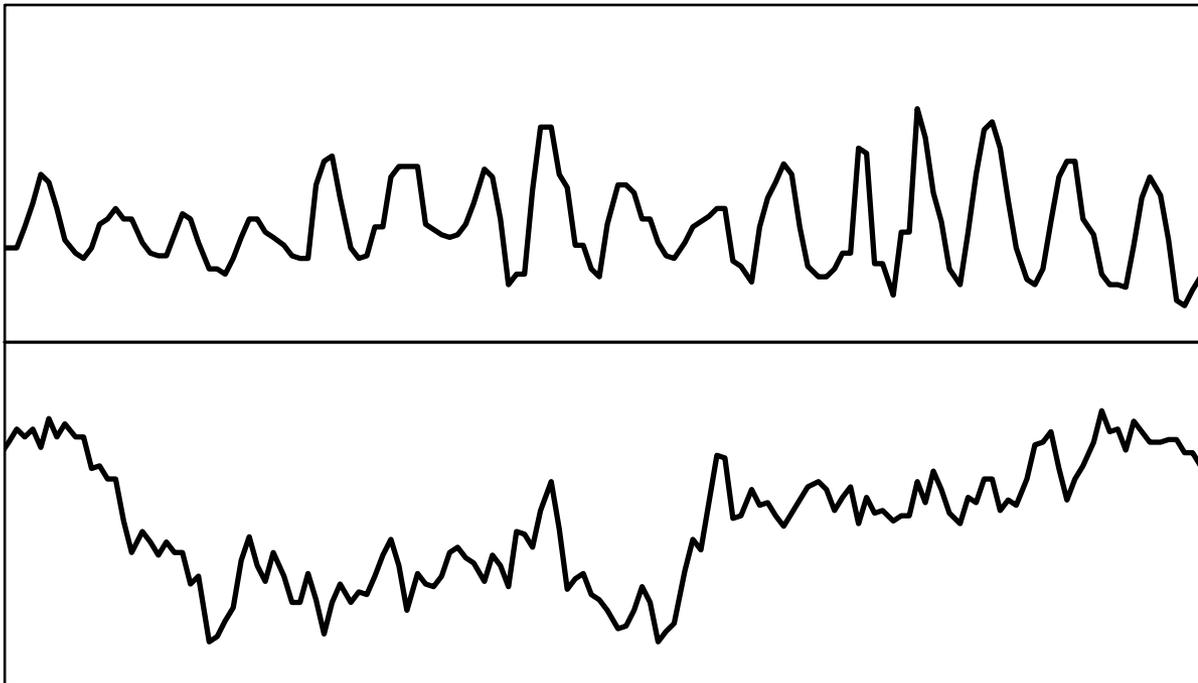
Problem Analysis

Controller in Manual

- Some loops: Okay to be in manual
  - Redundant, standby equipment
  - Certain process modes
- All other loops should be in auto
  - Check reason for manual with operator
  - Review historical performance
  - Place in automatic mode to see response

Problem Analysis

```
Controller In Manual          Poor Performance in Auto
                                        |
                      +-----------------+-----------------+
                      |                                   |
                 Oscillations                      Random Deviations
                      |                                   |
          +-----------+-----------+              +--------+--------+
          |           |           |              |                 |
    Externally   Internally   Cyclical     Measurement        Disturbance
    Caused       Caused       Interaction  Noise
          |           |                                      |
     +----+----+  +---+----+                    +------------+------------+
     |         |  |        |                    |            |            |
  Through   Through Valve  Tuning            Valve        Tuning       Fast
  Set Point Process Problem                  Problem                   Disturbances
```
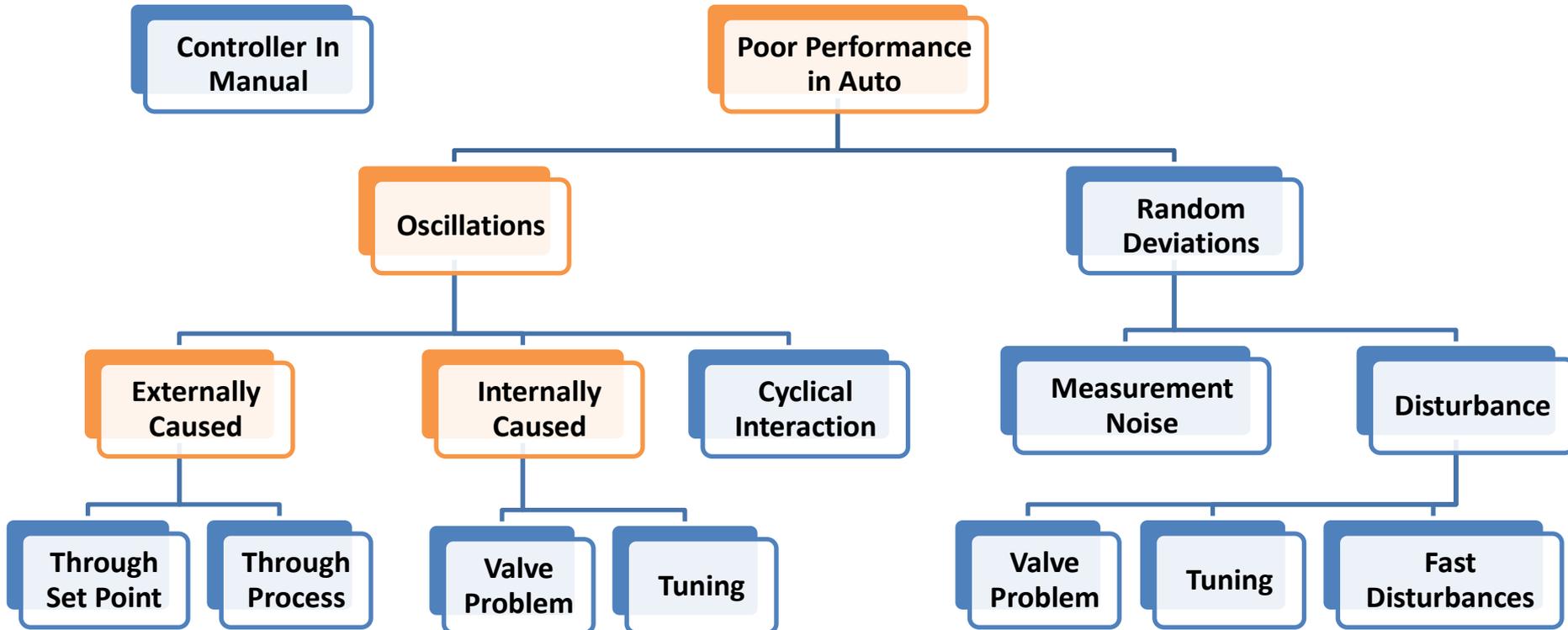
Cyclical or Random

▶ Analyze process variable to determine
 – Visually
 – Use frequency analysis software
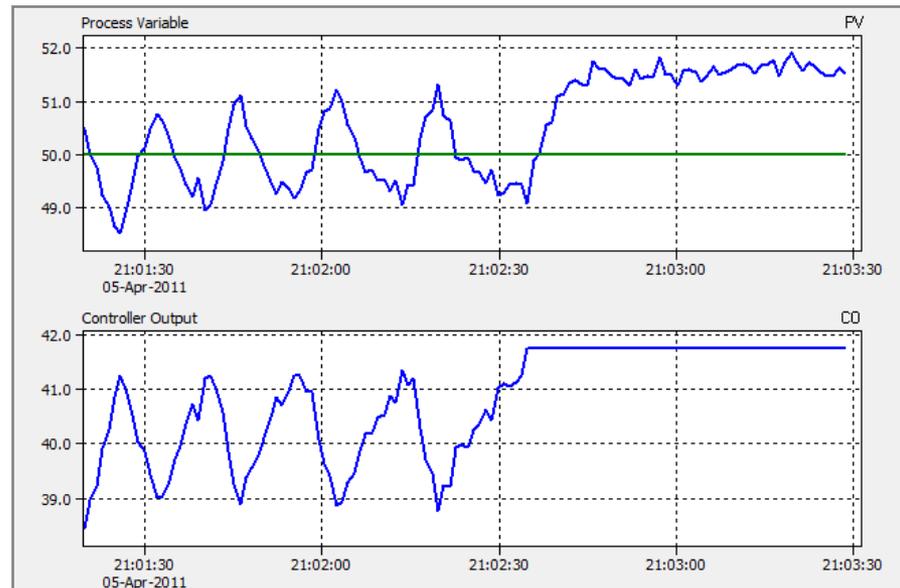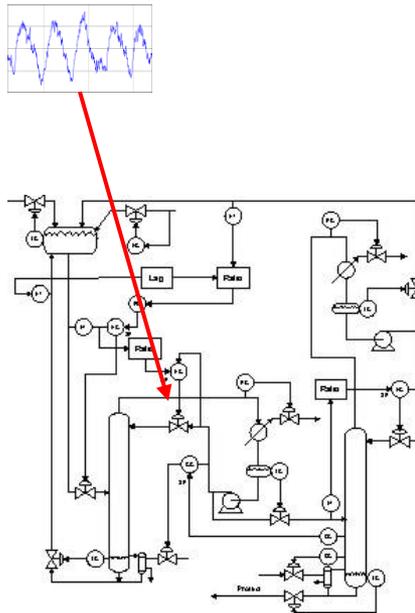

Oscillations have a repeatable, constant period
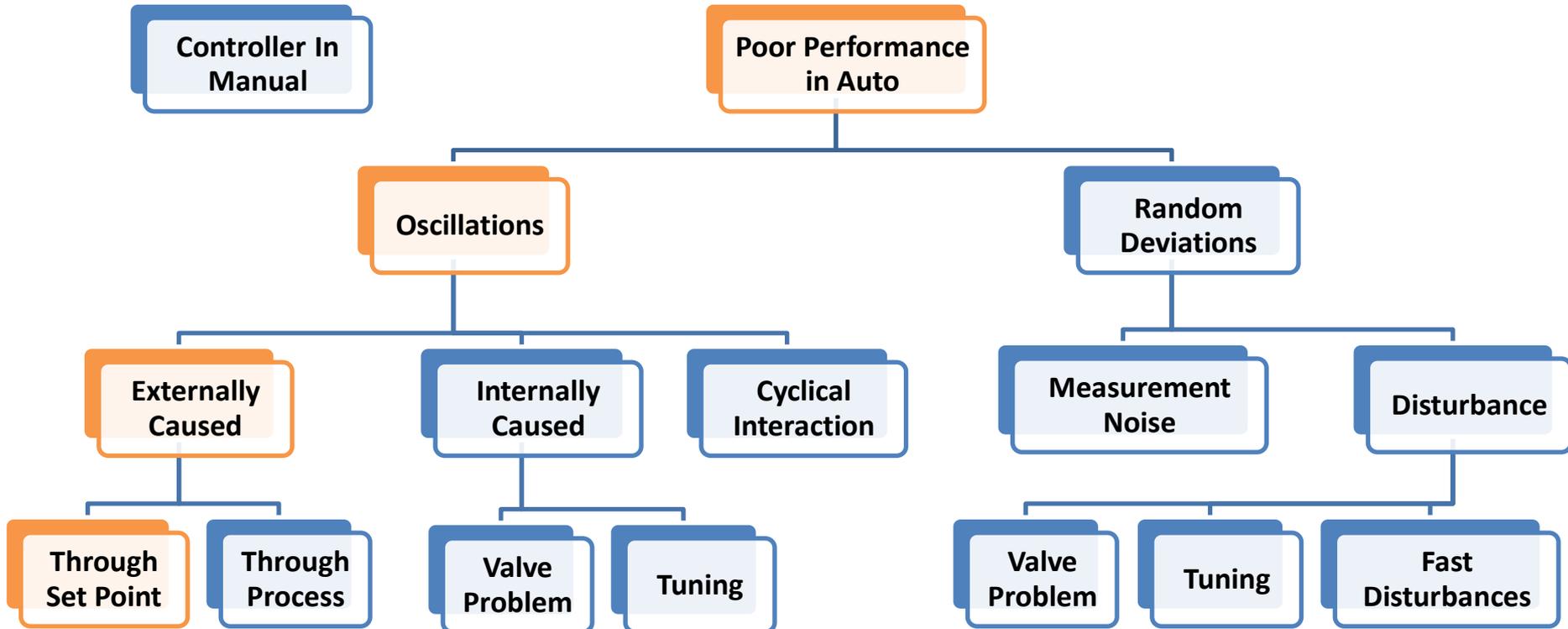
Noise and disturbances are random

Problem Analysis

```
Controller In Manual

Poor Performance in Auto
├── Oscillations
│   ├── Externally Caused
│   │   ├── Through Set Point
│   │   └── Through Process
│   ├── Internally Caused
│   │   ├── Valve Problem
│   │   └── Tuning
│   └── Cyclical Interaction
└── Random Deviations
    ├── Measurement Noise
    │   ├── Valve Problem
    │   └── Tuning
    └── Disturbance
        └── Fast Disturbances
```

Internal vs. External Oscillations

▸ Diagnostic Test: Place loop in manual

▸ PV continues to oscillate $\Rightarrow$ external source
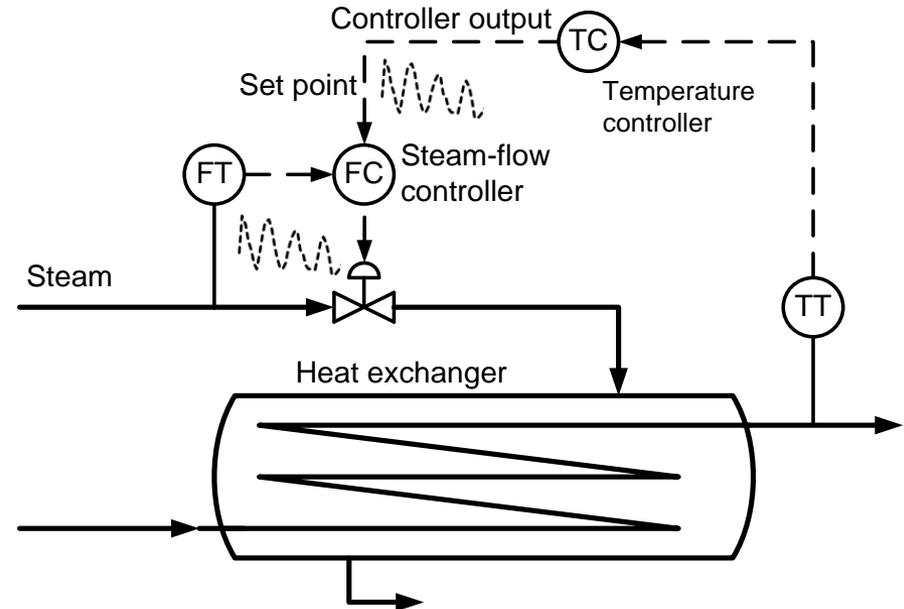
▸ Oscillation ceases $\Rightarrow$ internal problem

Problem Analysis

```
Controller In Manual          Poor Performance in Auto
                              ┌──────────┴──────────┐
                         Oscillations          Random Deviations
                    ┌────────┼────────┐      ┌────────┴────────┐
              Externally  Internally  Cyclical   Measurement   Disturbance
              Caused      Caused      Interaction Noise
           ┌─────┴─────┐ ┌───┴───┐          ┌──────┬──────┐
        Through   Through Valve   Tuning   Valve  Tuning  Fast
        Set Point Process Problem          Problem        Disturbances
```
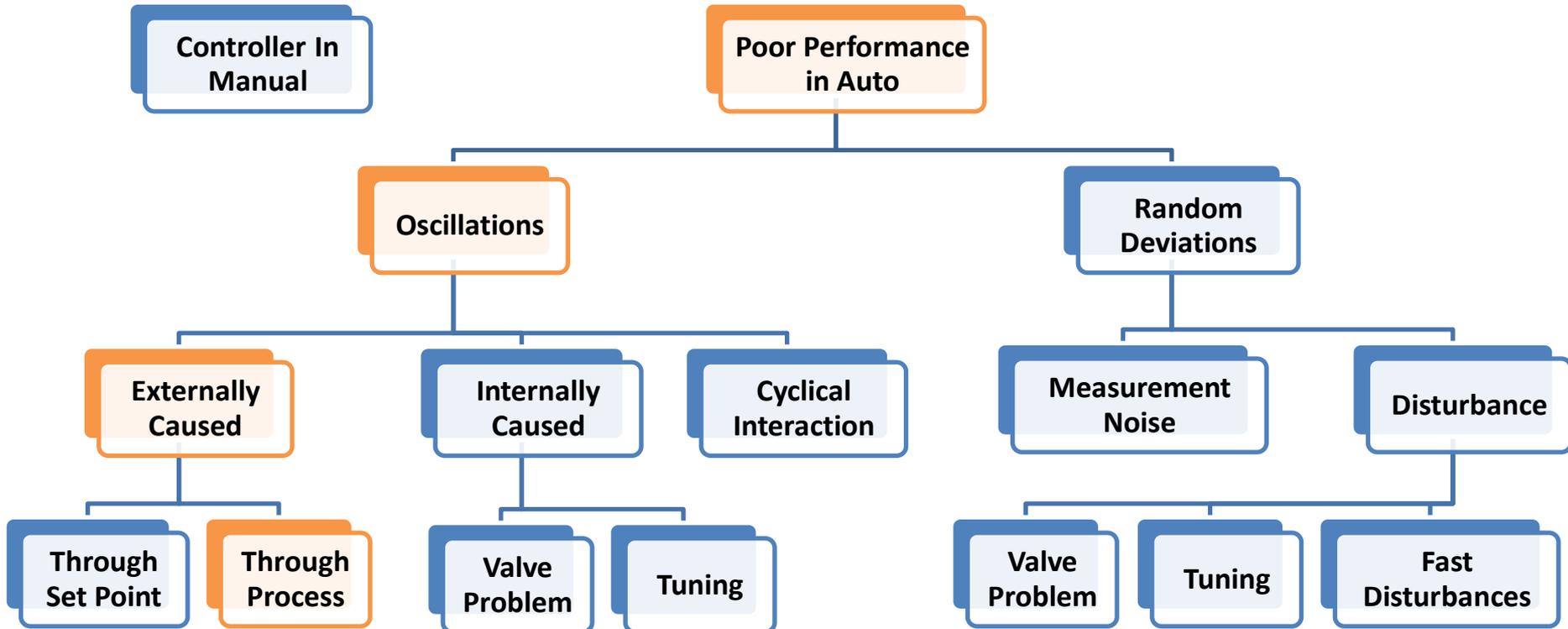
Oscillating Set Point

- ▸ E.g. steam flow loop oscillates and its set point oscillates

- ▸ Place temperature loop in manual
  - – Flow loop stops oscillating: analyze temperature loop
 - – Flow loop still oscillates: analyze flow loop

Controller output

Set point

Steam-flow controller

Temperature controller

FT

FC

TC

TT

Steam

Heat exchanger

Problem Analysis

Controller In Manual

Poor Performance in Auto
- Oscillations
  - Externally Caused
    - Through Set Point
    - Through Process
  - Internally Caused
    - Valve Problem
    - Tuning
  - Cyclical Interaction
- Random Deviations
  - Measurement Noise
  - Disturbance
    - Valve Problem
    - Tuning
    - Fast Disturbances

Interaction through Process

▶ Interactive process

- Heat integration, recycle, etc.

▶ Oscillating loop elsewhere

▶ Affects other loops

▶ Interaction analysis tools

- PAS, ExperTune, Matrikon

▶ P&ID and Process Historian

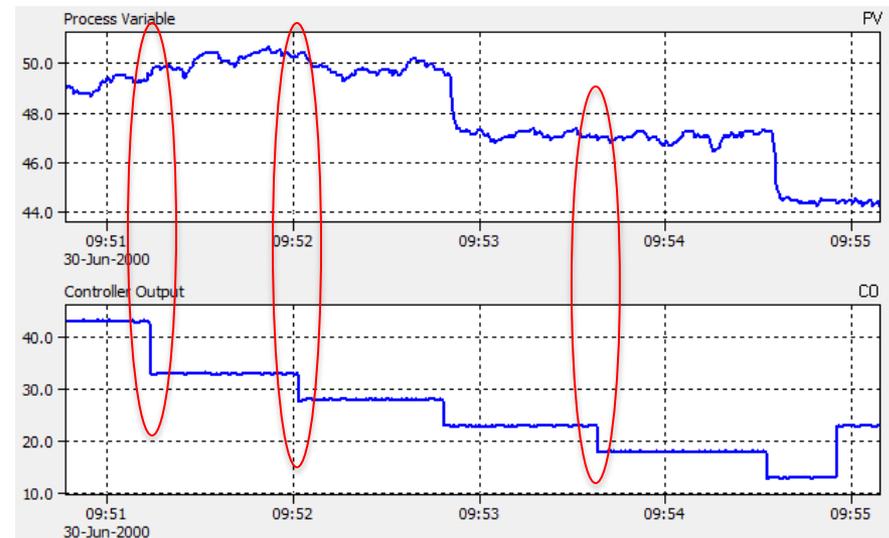▶ Look for leading oscillation

▶ Look at shape of oscillation
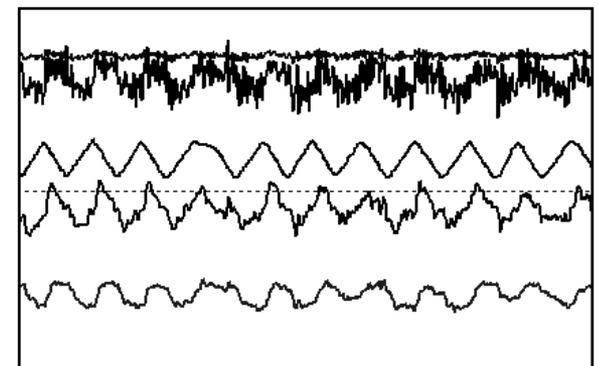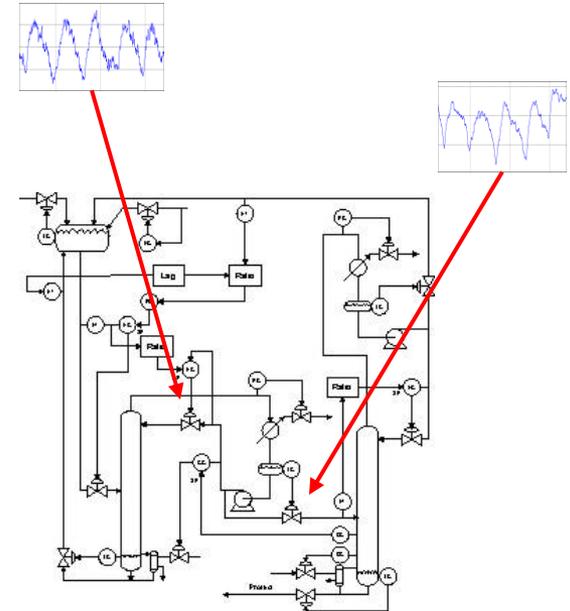
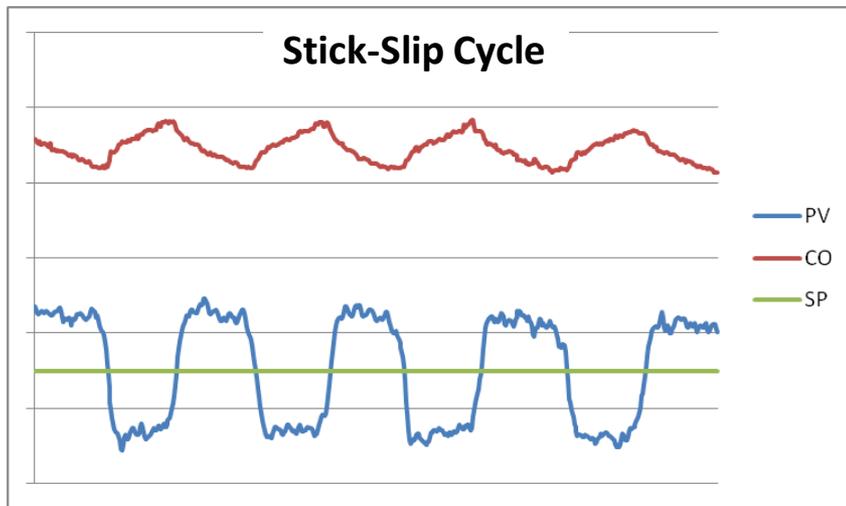# Problem Analysis
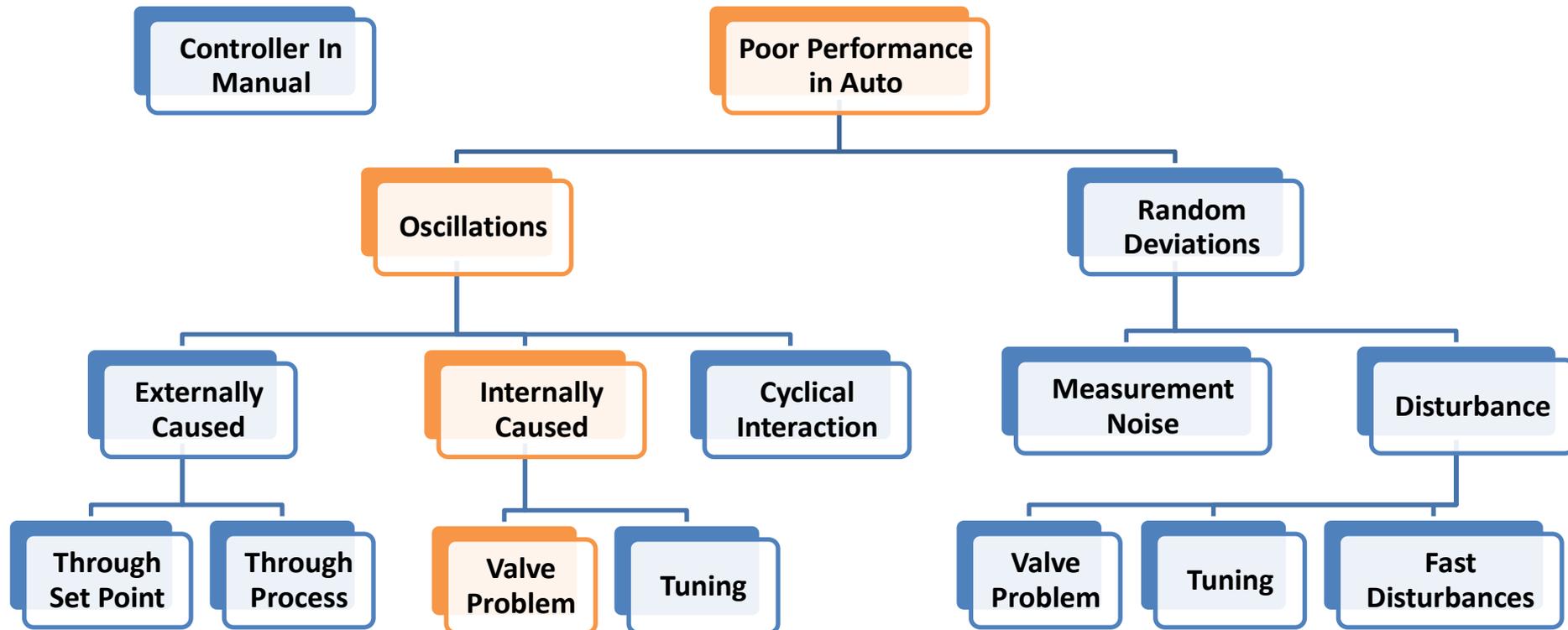
Stiction
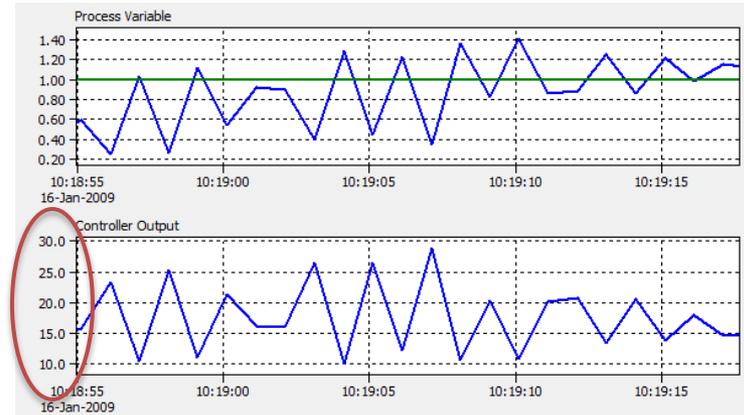
- Short for "Static Friction"
- Final control element is sticky
- Can cause a "stick-slip" cycle with loop in auto
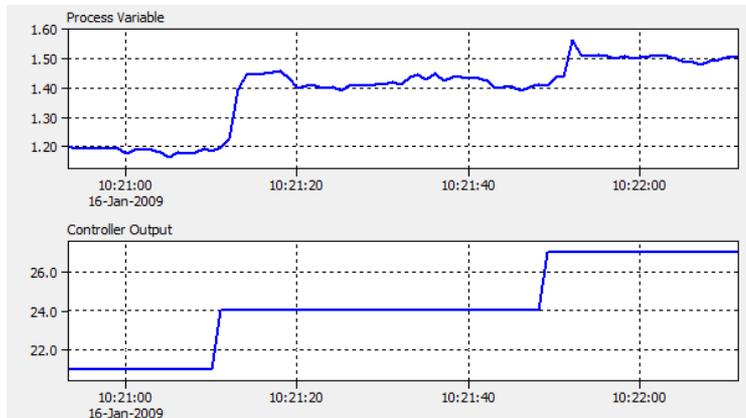- Stiction test: small controller output changes

White water flow controller

Positioner Problem
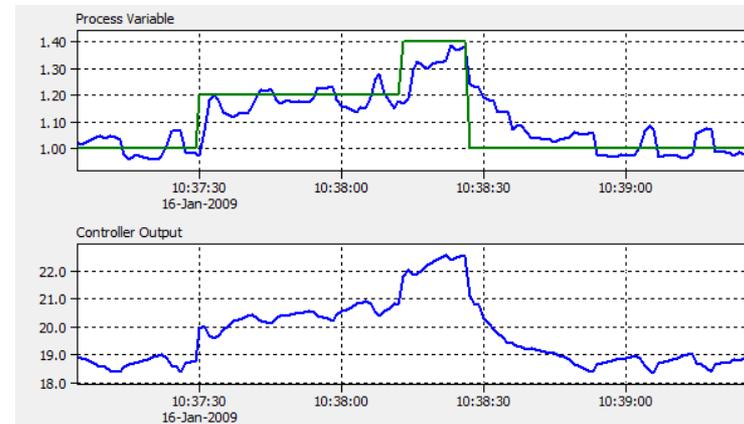
- Defective positioner
- Incorrectly tuned positioner
- Sticky valve
- Revealed through small step tests

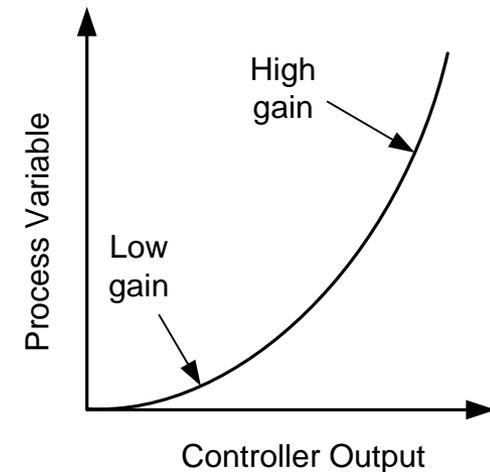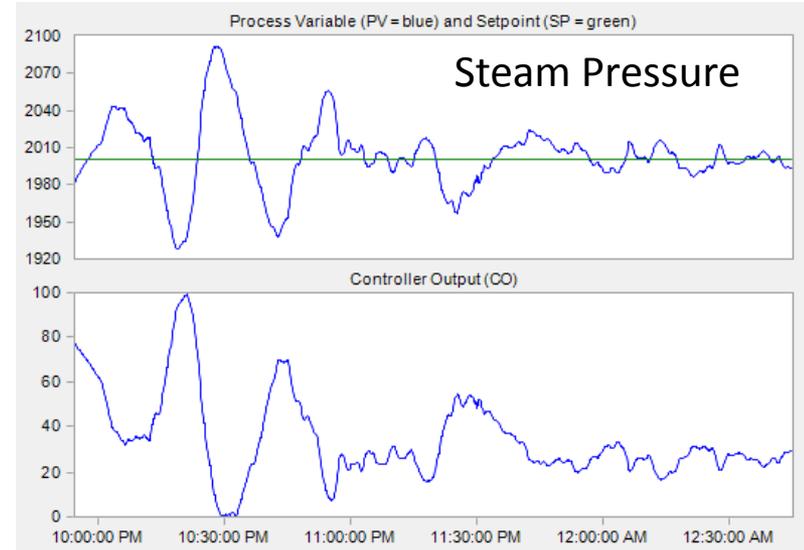HP Flare Scrubber Flow Control as found – oscillating severely

Step tests revealed positioner overshoot

After tuning – still oscillating because of stiction, but much less

Nonlinearity

- Loop unstable under certain conditions
- Nonlinear valve characteristic
  - Plot Flow vs. % Open
  - Use characterizer
- Nonlinear process
  - Tune under different conditions
  - Use gain scheduling

Problem Analysis

```
Controller In Manual

Poor Performance in Auto
├── Oscillations
│   ├── Externally Caused
│   │   ├── Through Set Point
│   │   └── Through Process
│   ├── Internally Caused
│   │   ├── Valve Problem
│   │   └── Tuning
│   └── Cyclical Interaction
└── Random Deviations
    ├── Measurement Noise
    │   ├── Valve Problem
    │   └── Tuning
    └── Disturbance
        └── Fast Disturbances
```

Controller Tuning Methods
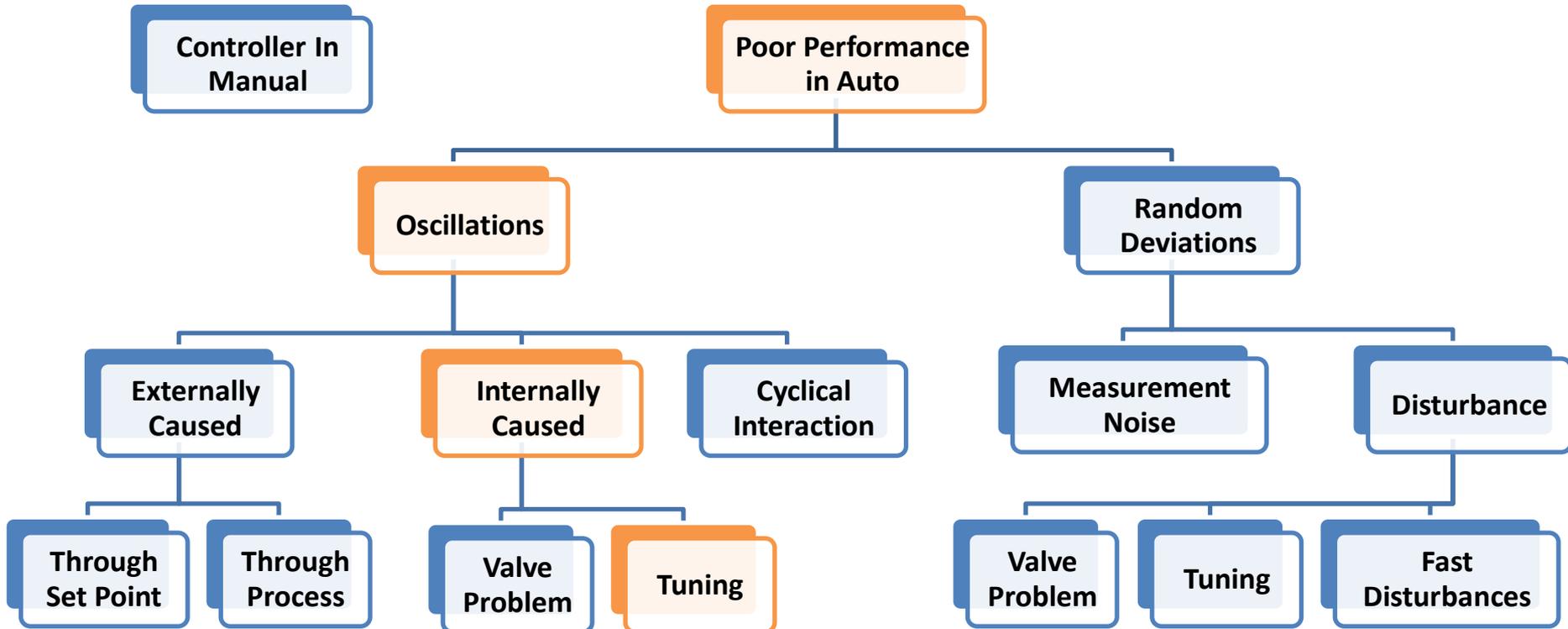
▸ Tune controller according to the process characteristics

▸ Tune controllers to meet control objective

▸ Trial-and-error tuning

▸ Tuning rules

▸ Tuning software

Better Results
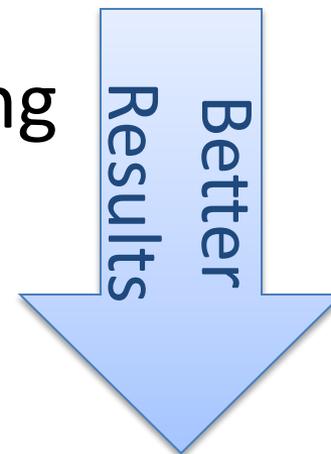
Tuning Example

▶ Oil-Gas Separator Level Control
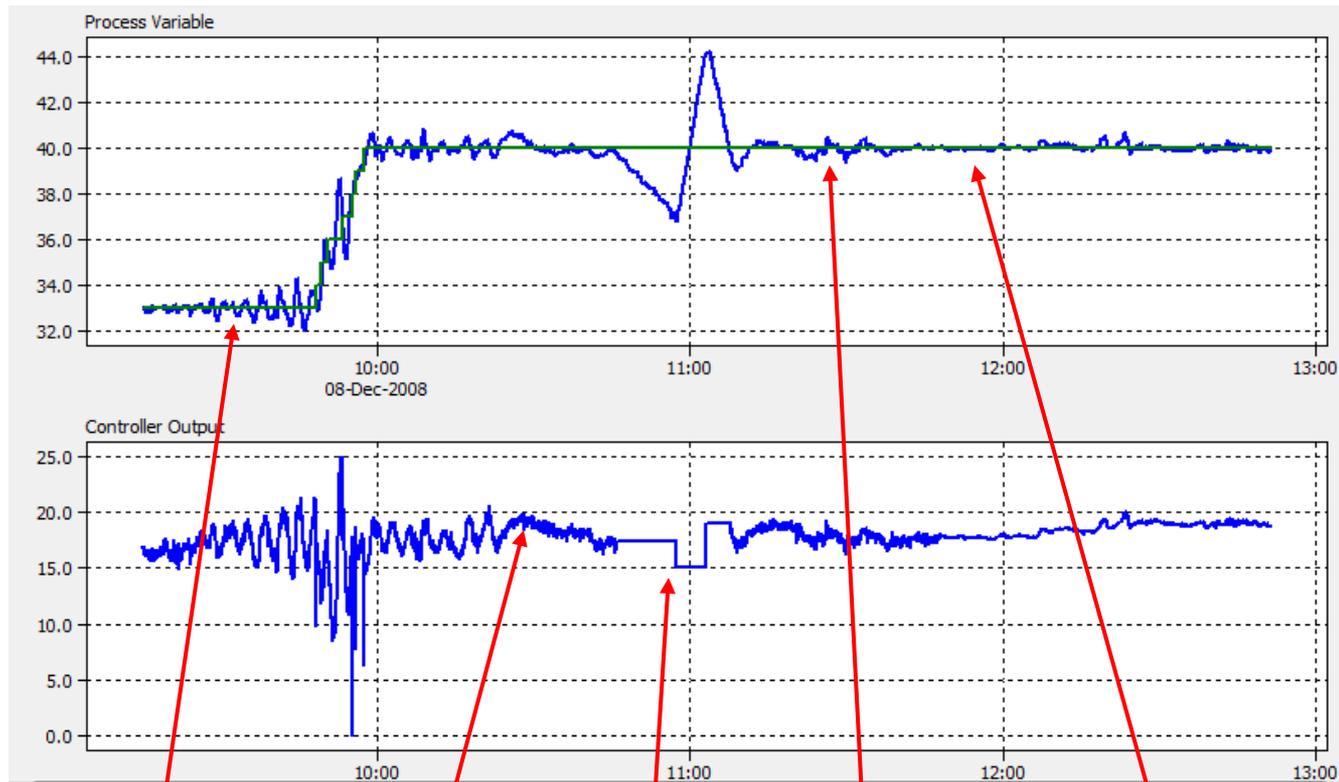

As Found   Quick Stabilization   Step Tests   After Tuning   With PV Filter

Problem Analysis

Controller In Manual

Poor Performance in Auto

- Oscillations
  - Externally Caused
    - Through Set Point
    - Through Process
  - Internally Caused
    - Valve Problem
    - Tuning
  - Cyclical Interaction
- Random Deviations
  - Measurement Noise
  - Disturbance
    - Valve Problem
    - Tuning
    - Fast Disturbances
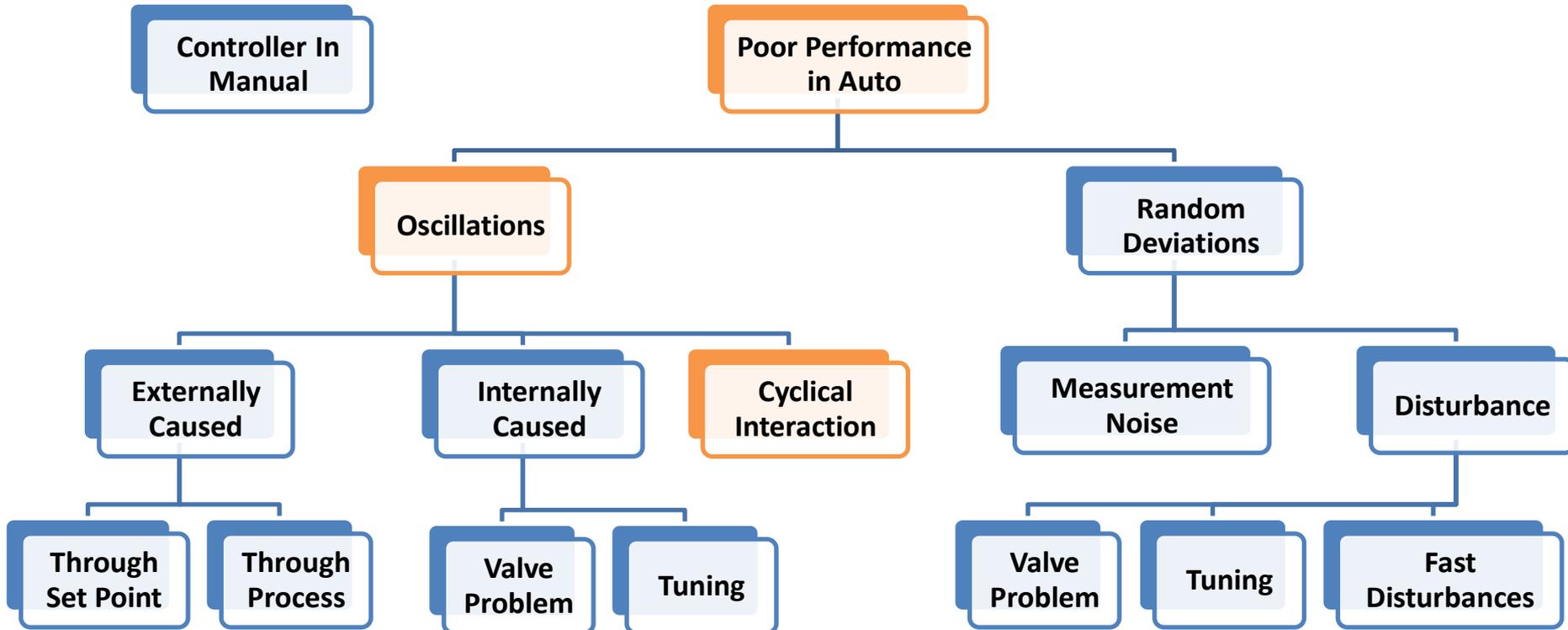
Cyclical Interaction

▸ Loops "fighting" with each other

▸ Continuous, interactive oscillations

- – Strong interaction
- – Similar dynamics
- – Aggressive tuning

Solutions for Interactive Loops
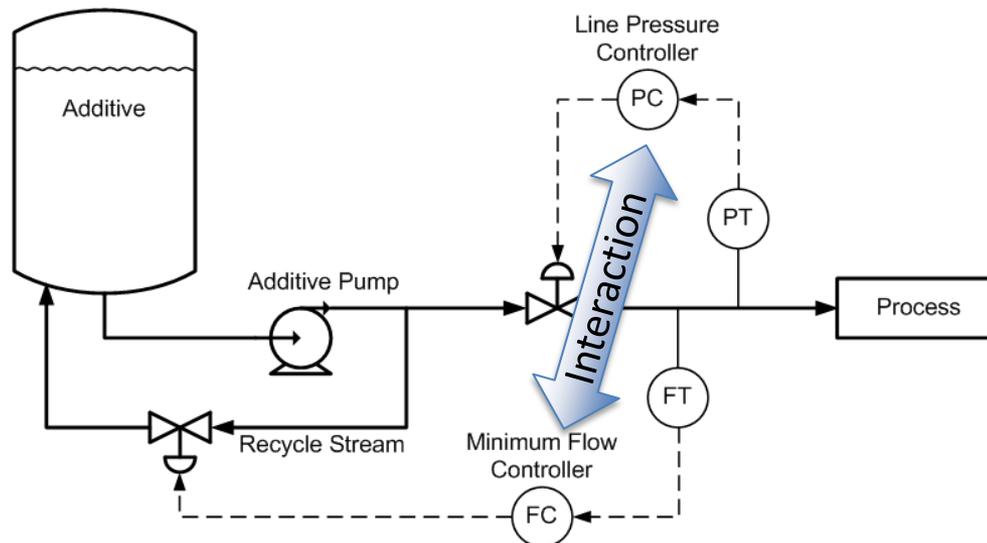
▶ Dynamically separate loop response times
  – Tune most important loop for fast response
  – Tune interacting loop to respond 3 x slower

▶ Apply dynamic decoupling
  – Two cross-coupled feedforward controllers between loops

▶ Implement MPC

Problem Analysis

Controller In Manual
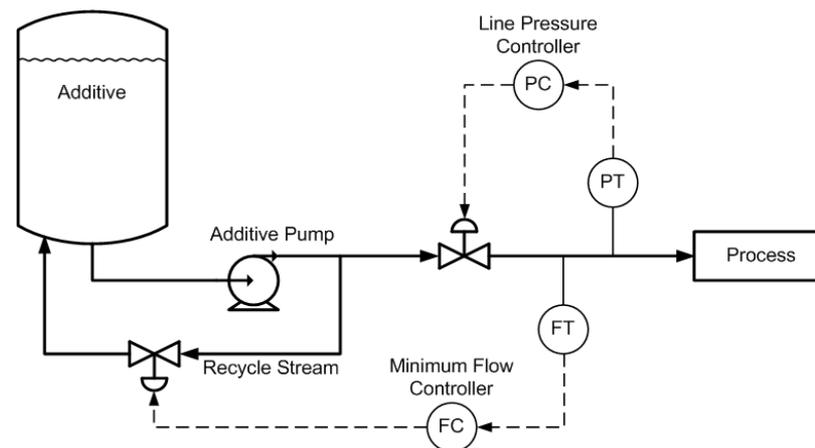
Poor Performance in Auto
- Oscillations
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    - Tuning
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- Random Deviations
  - Measurement Noise
    - Valve Problem
    - Tuning
  - Disturbance
    - Fast Disturbances
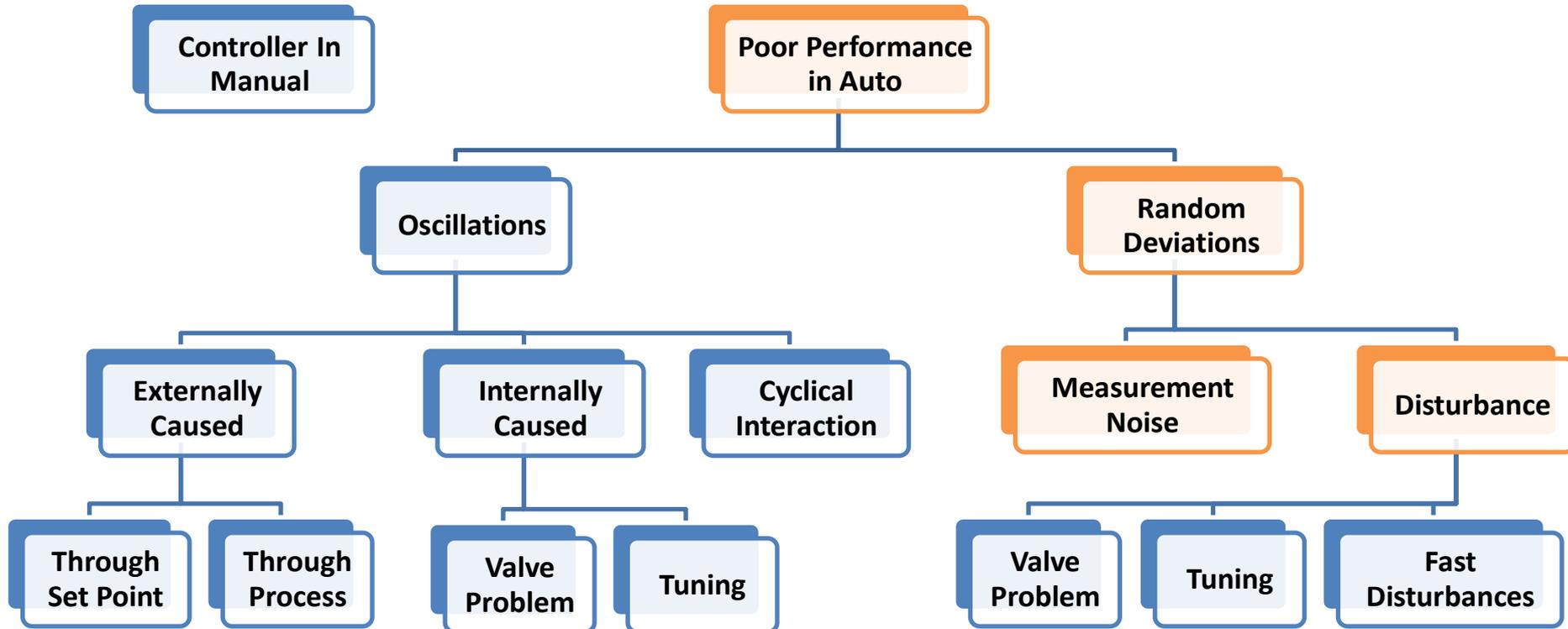
Noise or Disturbance

▶ Noise is fast changes

▶ Disturbances are longer in duration

▶ Can coexist

▶ Noise can be filtered
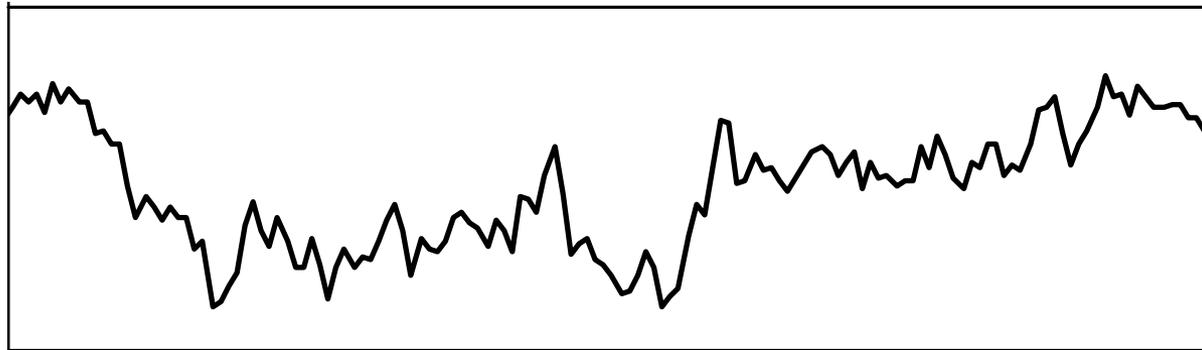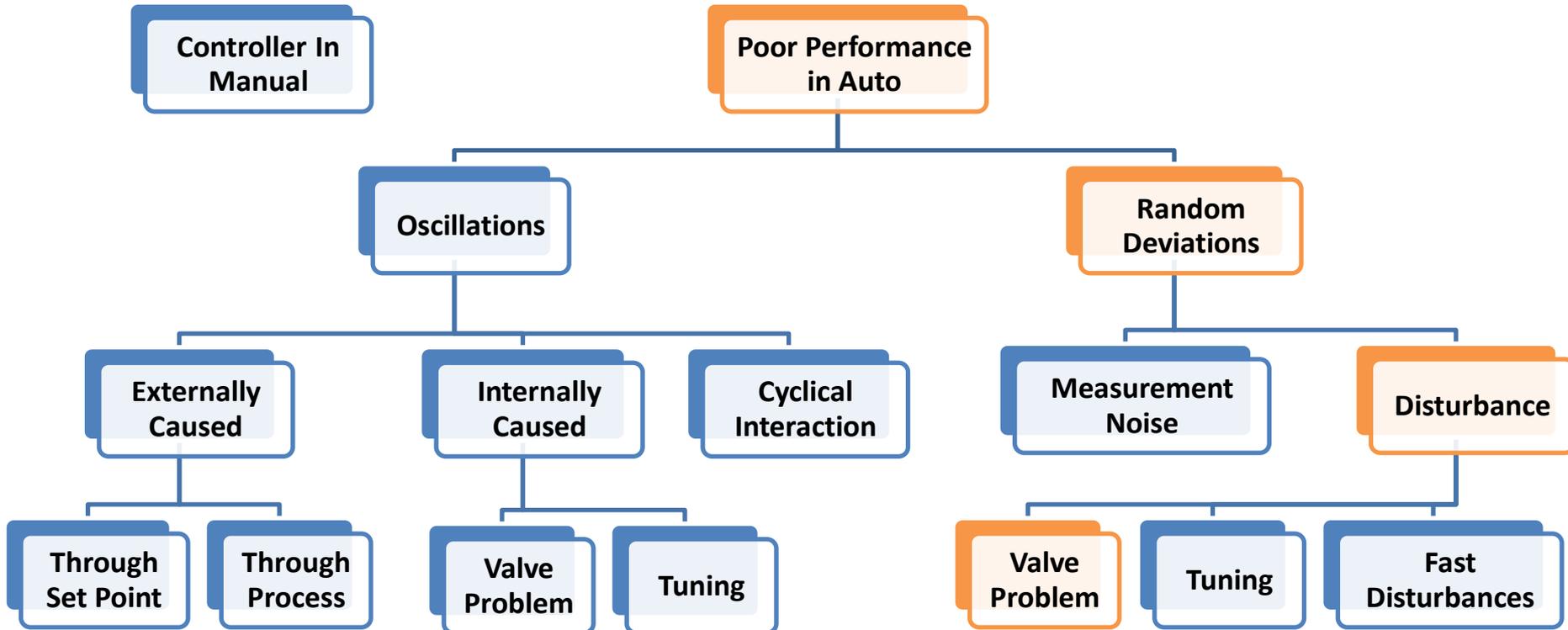
Problem Analysis

```
                                        Poor Performance
Controller In                               in Auto
   Manual
                              ┌──────────────────┴──────────────────┐
                         Oscillations                          Random
                                                              Deviations
                  ┌───────────┼───────────┐              ┌────────┴────────┐
              Externally   Internally   Cyclical     Measurement      Disturbance
               Caused       Caused     Interaction      Noise
              ┌────┴────┐   ┌────┴────┐              ┌──────┬──────┐
          Through   Through  Valve  Tuning        Valve  Tuning   Fast
          Set Point Process Problem              Problem      Disturbances
```
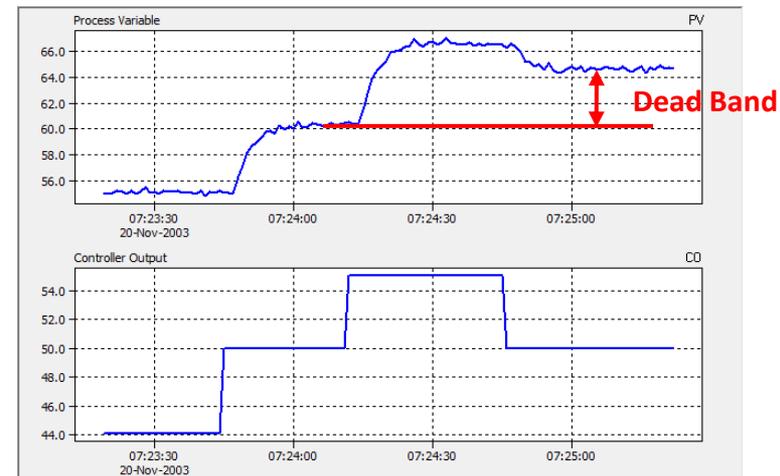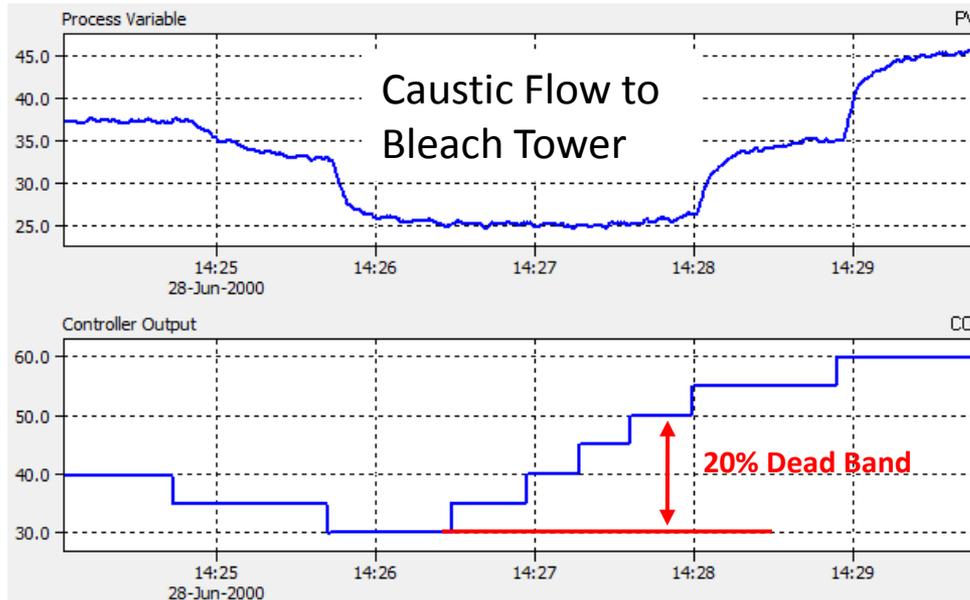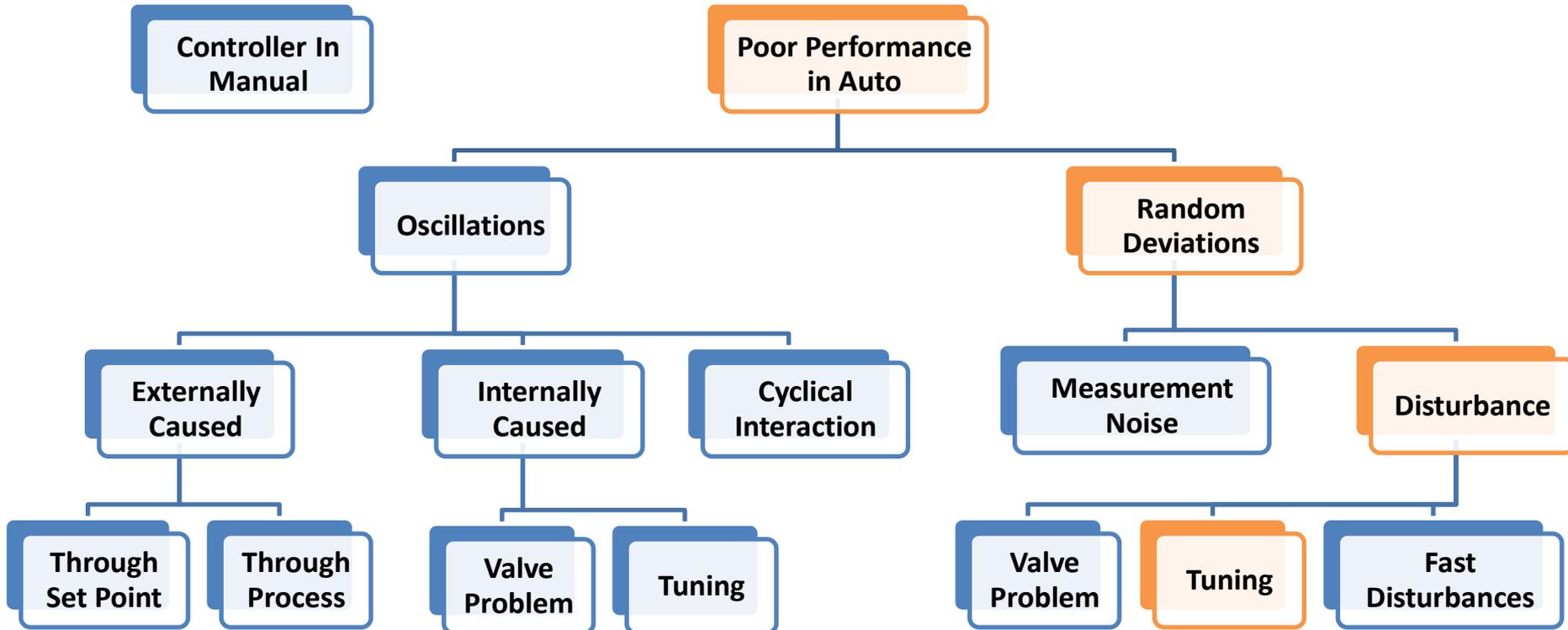
Dead Band (Hysteresis)

▸ Dead band between CO and PV

▸ Appears like sluggish control action

▸ Can result in very incorrect tuning calculations

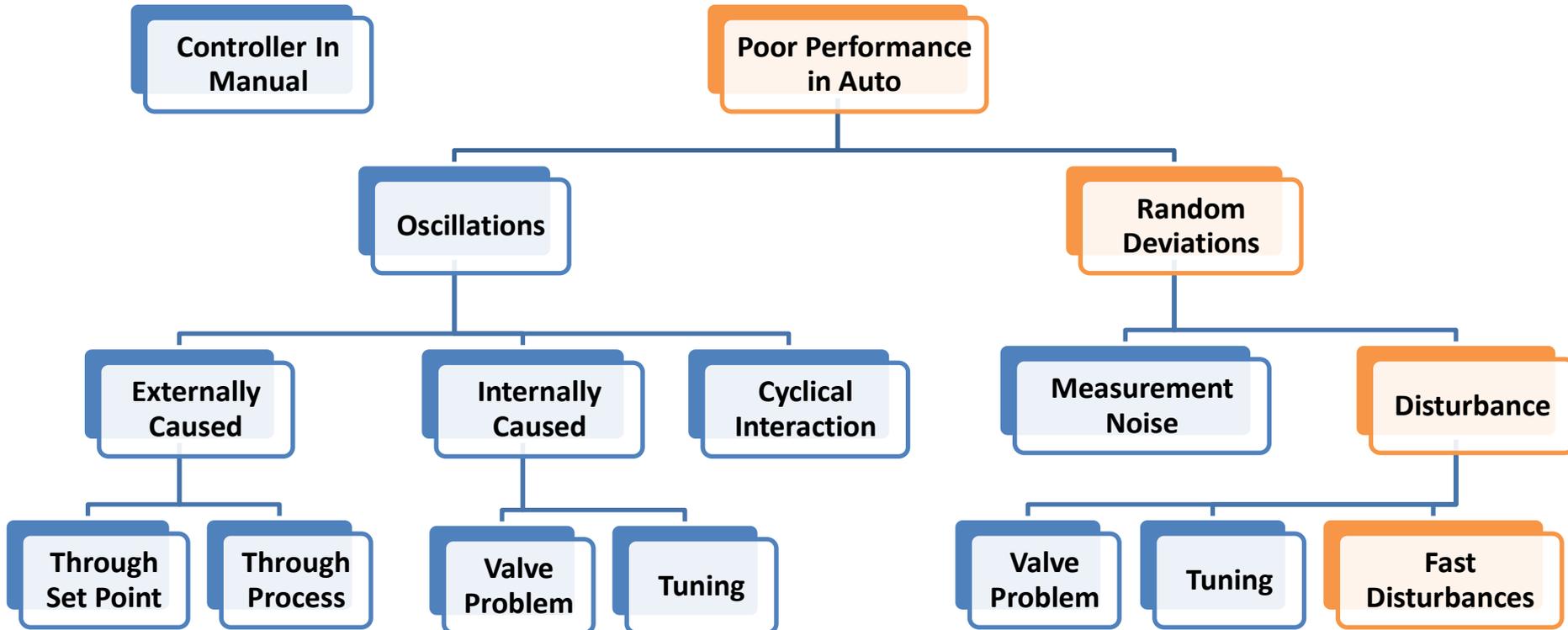▸ Dead-band test: 2 steps + 1 in opposite direction

Caustic Flow to Bleach Tower

20% Dead Band

Dead Band

Dead-Band Test

Problem Analysis

```
Controller In                    Poor Performance
Manual                              in Auto
                                         │
              ┌──────────────────────────┴──────────────────────────┐
         Oscillations                                          Random
                                                              Deviations
              │                                                   │
   ┌──────────┼──────────┐                              ┌─────────┴─────────┐
Externally  Internally  Cyclical                   Measurement         Disturbance
Caused      Caused      Interaction                Noise
   │           │                                                        │
┌──┴──┐     ┌──┴──┐                                          ┌──────────┼──────────┐
Through  Through  Valve   Tuning                          Valve     Tuning    Fast
Set Point Process Problem                                 Problem             Disturbances
```
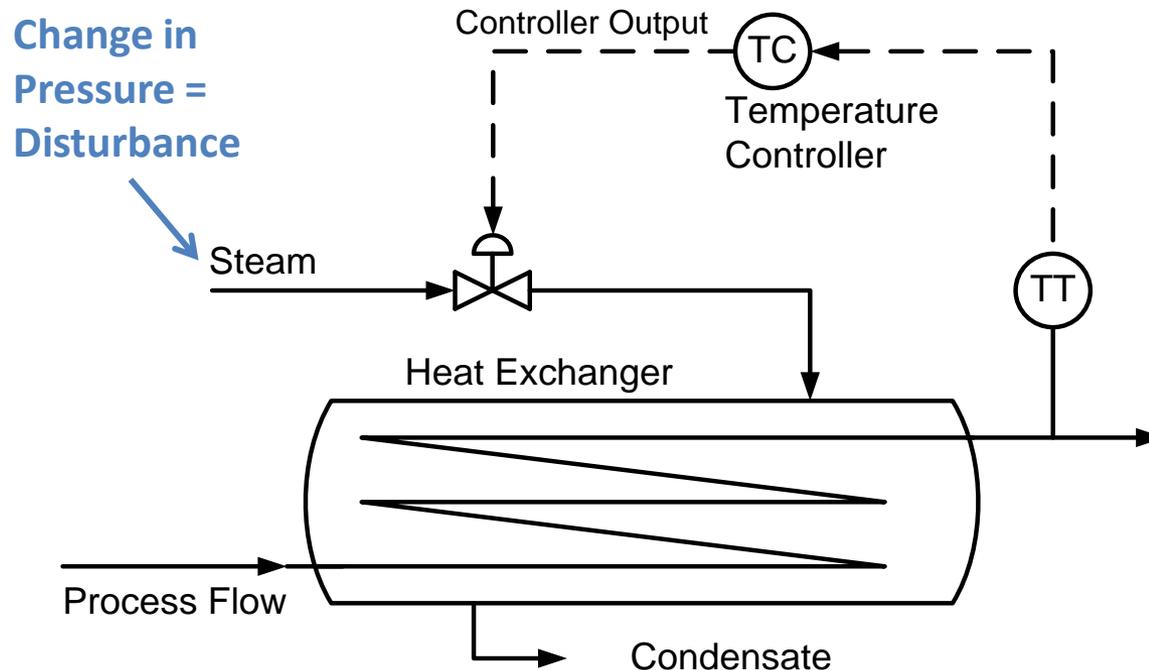
Tuning and Disturbance Rejection

▸ Previous comments about tuning apply

▸ Tuning (speed of response) has limits

   – Disturbance rejection

   – Settling time

▸ Limits mostly affected by dead time

▸ Other solutions are available
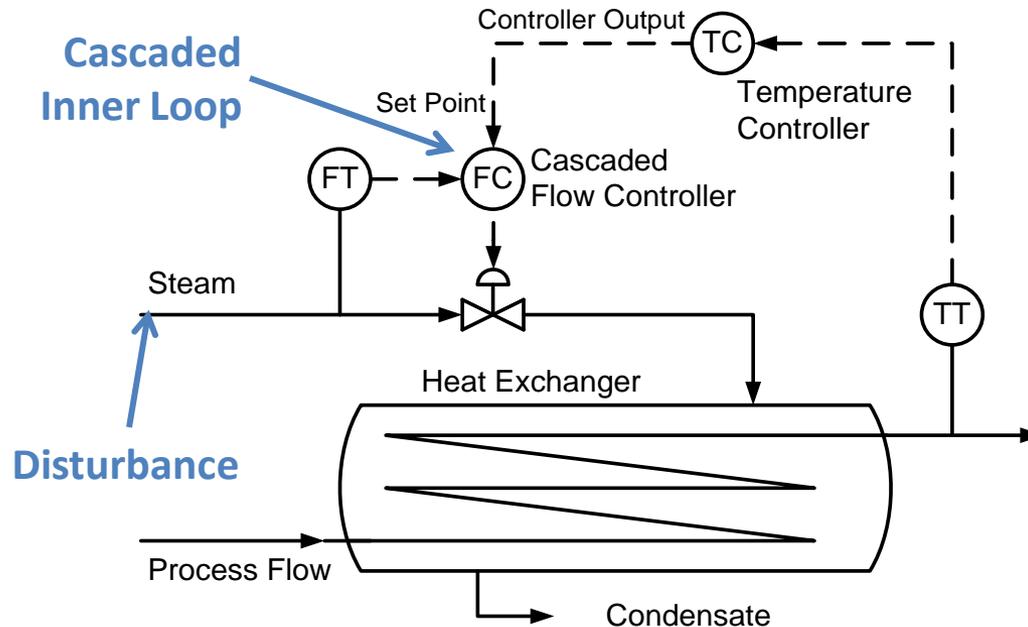
Problem Analysis

Control-Side Disturbances

▶ Go unnoticed until PV has been affected

▶ E.g. steam pressure to heat exchanger

Change in Pressure = Disturbance

Controller Output

TC

Temperature Controller

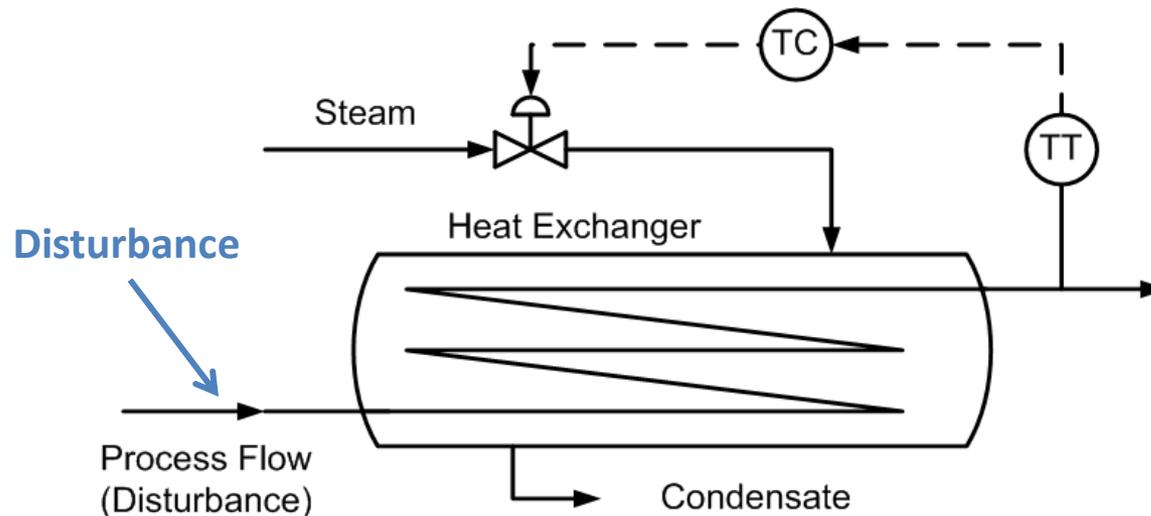Steam

TT

Heat Exchanger

Process Flow

Condensate

Solution: Cascade Control

- ▸ Cascade control isolates control-side disturbances, nonlinearities, valve problems
- ▸ Good practice for any slow control loop manipulating a flow

Process-Side Disturbances

▸ Go unnoticed until PV has been affected

▸ E.g. process flow through heat exchanger

Solution: Feedforward Control

- ▸ Use disturbance to drive control action
- ▸ Feedforward control action can cancel out effect of major disturbances
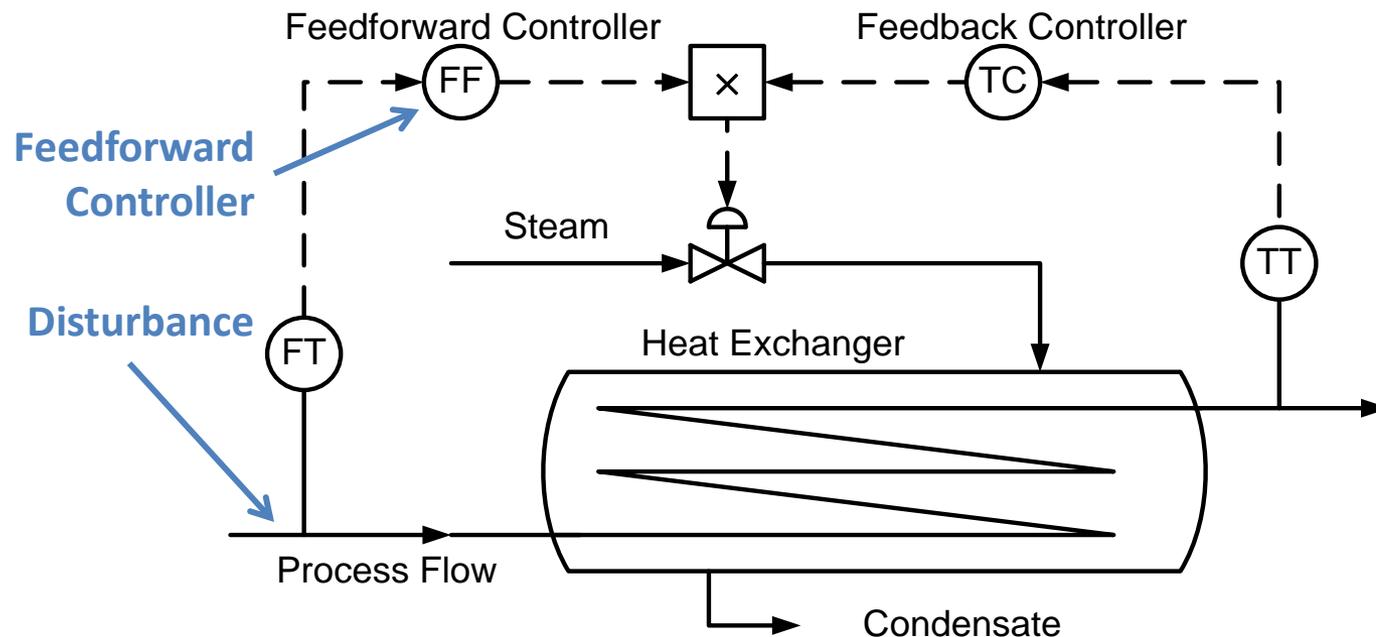
Summary

- Some poorly performing loops are a challenge to tune
- Realize that it might not be a tuning problem
- Do process tests to detect valve problems
- Valve problems require repairs, not tuning
- Tune from step test data using rules or software
- Know the limitations of tuning
- The problem may originate from outside the loop
- Eliminate variability at its source
- Enhance the control strategy where needed

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Questions?