Prescription to Performance

--The Search for the Holy Grail--

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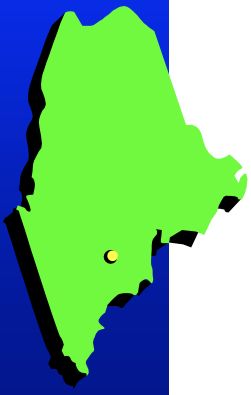


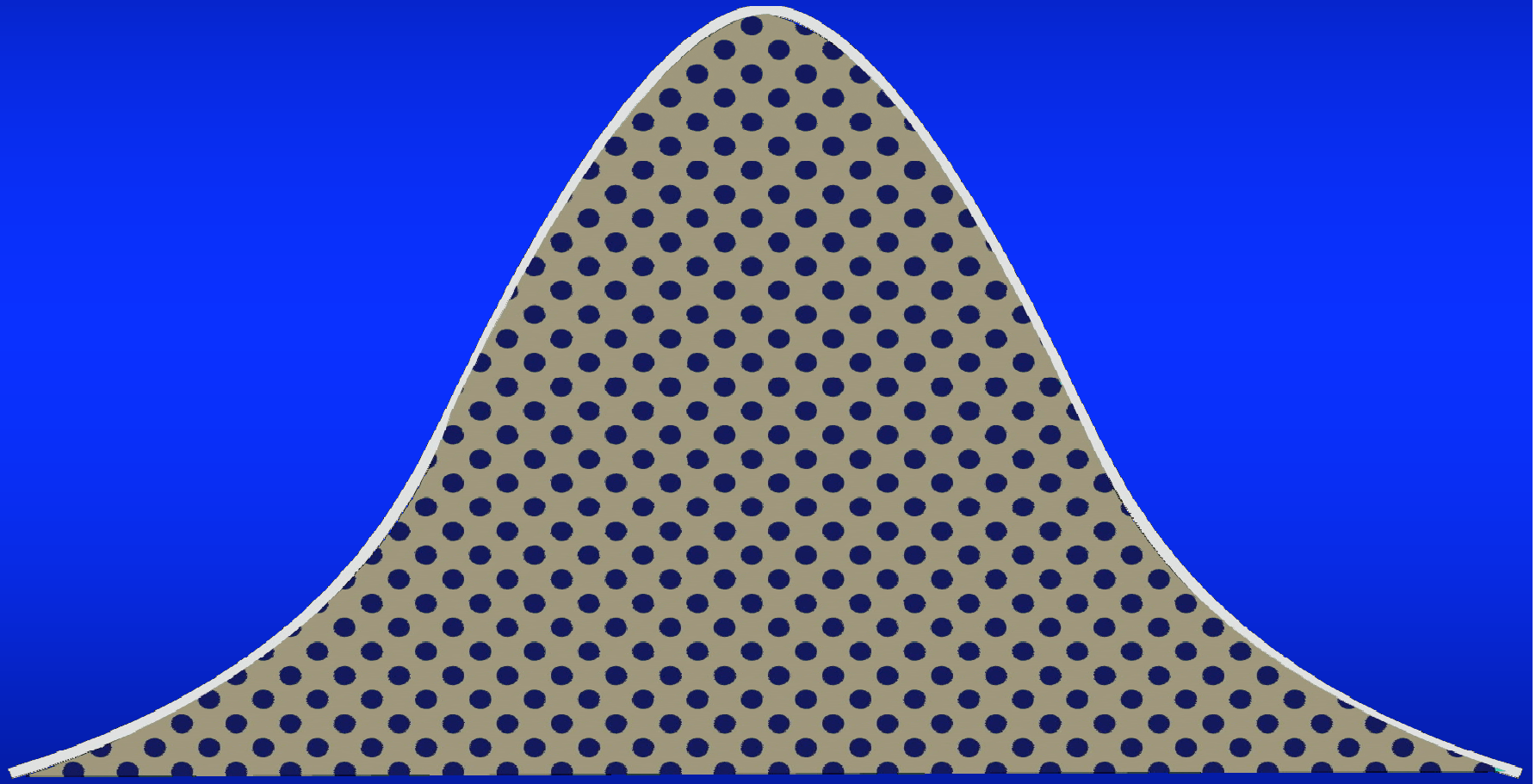
Topics

- Variability
- Discuss different types of specifications
- Discuss Maine's move away from prescriptive specifications for concrete

Inherent Variability

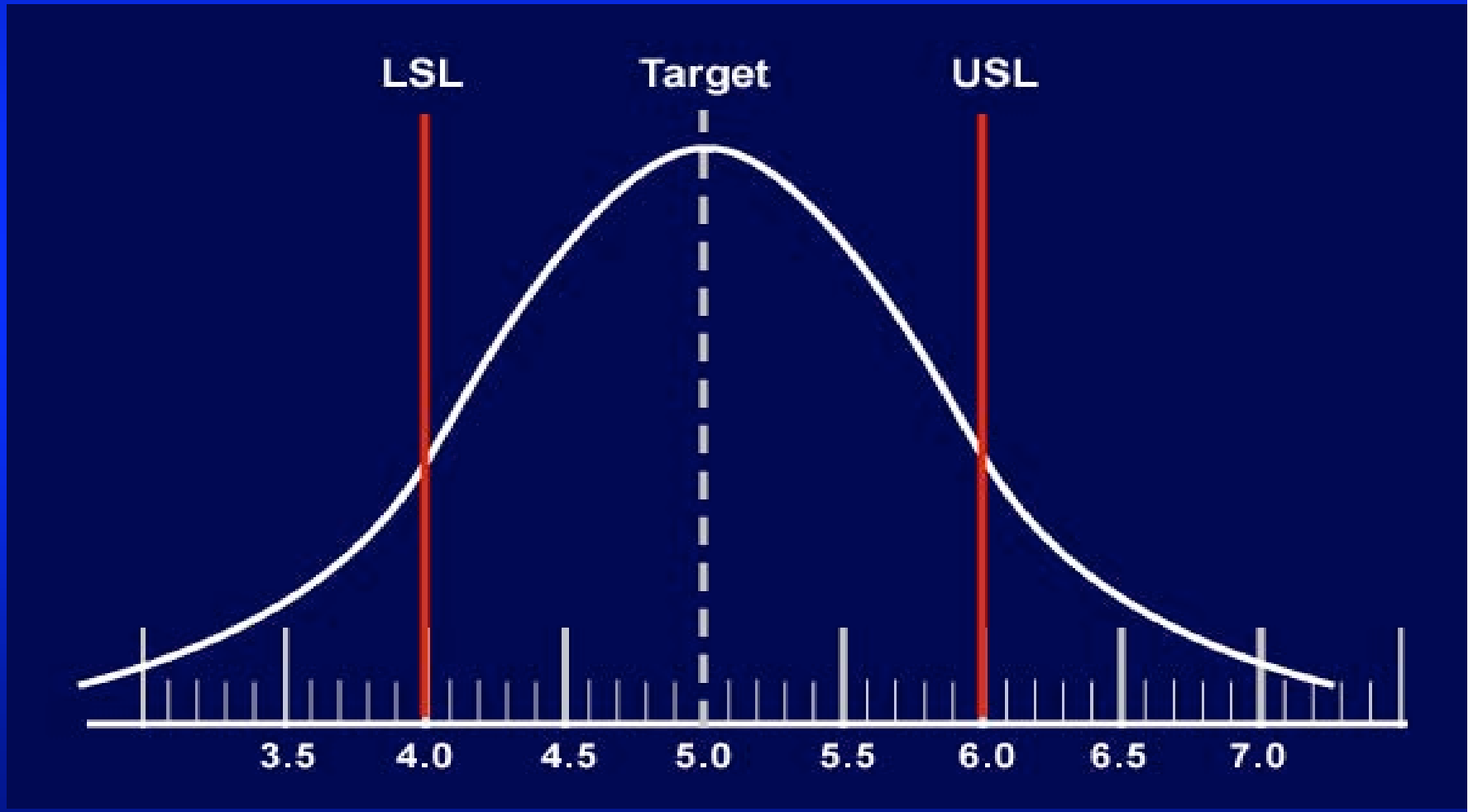
- There are four (4) primary components or sources of ***Inherent Variability*** in individual test results for material samples:
  - Sampling Variability
  - Testing Variability
  - Material Variability
  - Construction (Production and Placement) Variability

1958 AASHO Road Test: Normal Distribution



Property

Per Cent Within Limits (PWL)



Specifications--Some Definitions

- Method specifications
- End result specifications
- Quality assurance specifications
- Performance-related specifications
- Performance-based specifications

Method Specification
(aka Recipe specs, Prescriptive specs)

- Specifications that require the Contractor to produce and place a product using specified materials in definite proportions and specific types of equipment and methods under the direction of the Agency.

- Contractor = Hired labor

Method Specifications
--Features--

- Provide “cookbook” directions for the contractor to follow
- Utilize agency inspection, sampling,and testing to control the work
- Acceptance based on “reasonable conformance” or “substantial compliance”
- 100% pay across a range of quality

Method Specifications
--Drawbacks--

- Does not allow for contractor innovation
- Acceptance decision is arbitrary, no defined quality levels
- Acceptance is statistically invalid
- Questionable legality of “reasonable conformance” or “substantial compliance”
- No financial reward for contractor providing superior quality

End Result Specifications

- Specifications that require the contractor to take the entire responsibility for producing and placing a product. The Agency's responsibility is to either accept or reject the final product or to apply a pay adjustment commensurate with the degree of compliance with the specifications.

End Result Specifications
--Features--

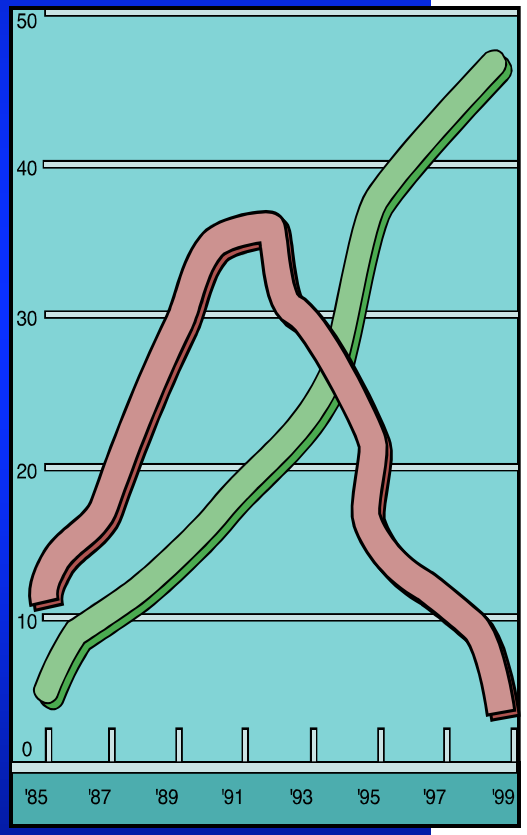
- Allow for maximum innovation; no controls on contractor methods or equipment
- Quality Control at the discretion of the contractor
- Acceptance of the final product
- Pay adjustment based on specification compliance

End Result Specifications
--Drawbacks--

- Minimizes engineering knowledge of the Agency
  - Process controls
  - Inspection
- Little opportunity to correct deficiencies
- Acceptance target values based on "experience" rather than data
- Lawyer fodder

Quality Assurance Specifications

- Specifications that require Contractor Quality Control and Agency Acceptance activities throughout production and placement of a final product. Final acceptance is usually based on a statistical sampling of the measured quality level for key quality characteristics.



Quality Assurance Specifications
--Features--

- Clear delineation of QC and acceptance roles and responsibilities
- Recognizes inherent material and process variability (PWL)
- Agency identifies key quality measures and levels
- Rational pay according to quality

Quality Assurance Specifications
--Advantages--

- Statistically valid acceptance
  - Random sampling
  - Lot basis vs. single test
- Quality characteristics may be independently evaluated
- Full use of QC and agency inspection
- Real time feedback to production
- Rational basis for modifications to pay

Performance-related Specifications

- Specs that use quality characteristics and life cycle cost relationships that are correlated to product performance.

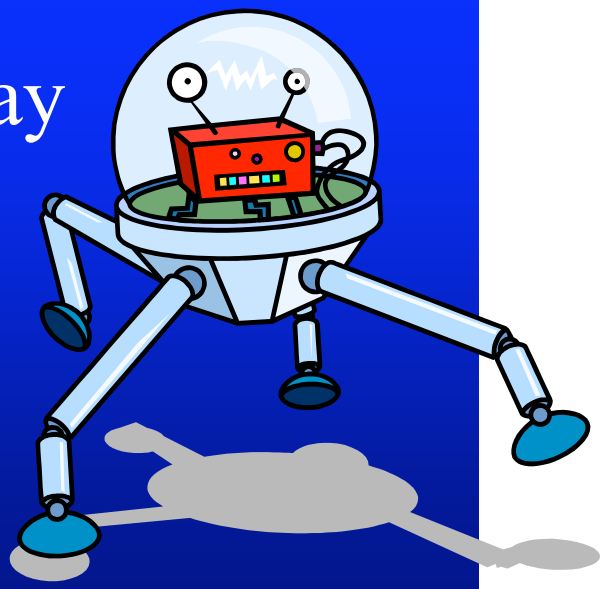
- Improved QA specs

Performance-related Specifications
--Features--

- Acceptance based on key quality characteristics that correlate fundamental engineering properties to performance
  - HMA: asphalt content or smoothness
  - Concrete: air content
- Mathematical models for LCC

Performance-based Specifications

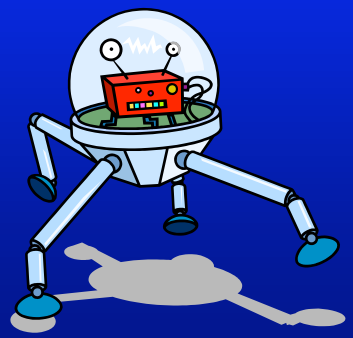
- QA specifications that describe the desired levels of fundamental engineering properties that are predictors of performance. Those properties predict performance and pay is adjusted accordingly.



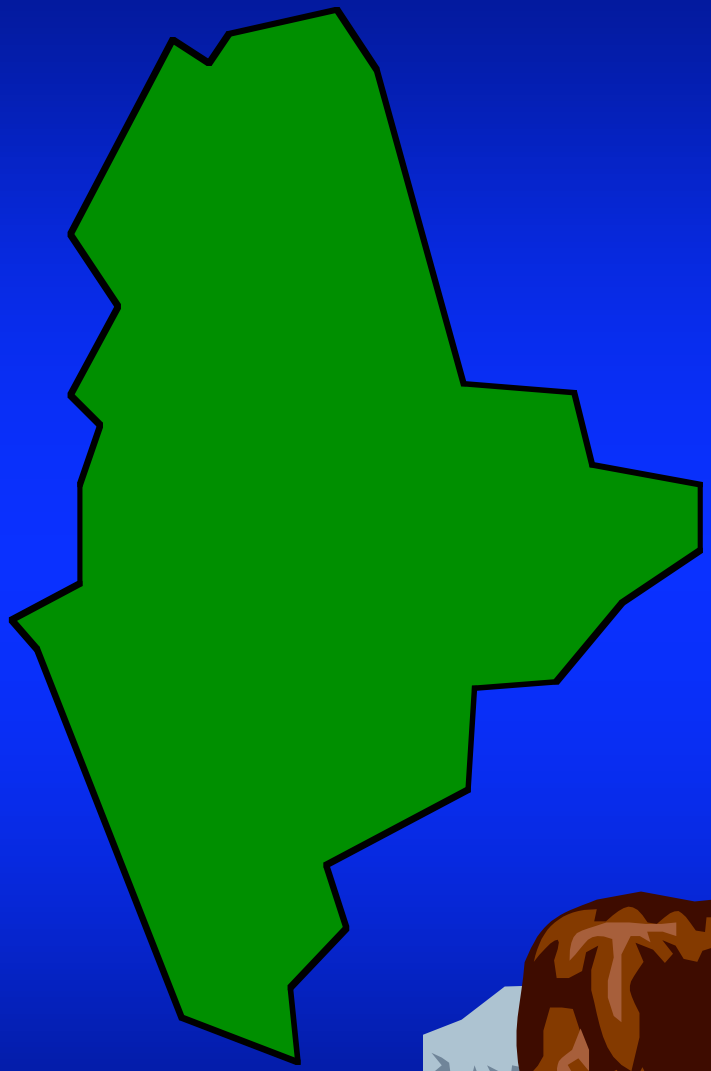
Performance-based Specifications
--Features--

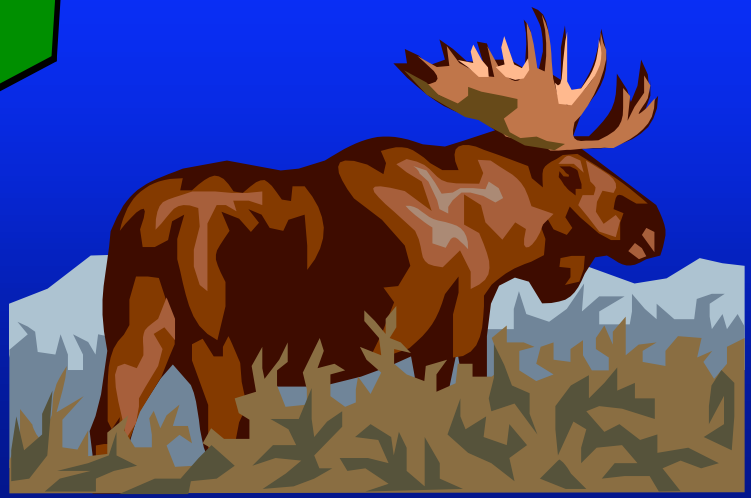
- Similar to performance-based but *engineering properties* are measured, not key quality characteristics
  - e.g. Fatigue resistance, creep properties, modulus
- LCC models that relate properties to performance

➢ Not developed yet



Maine

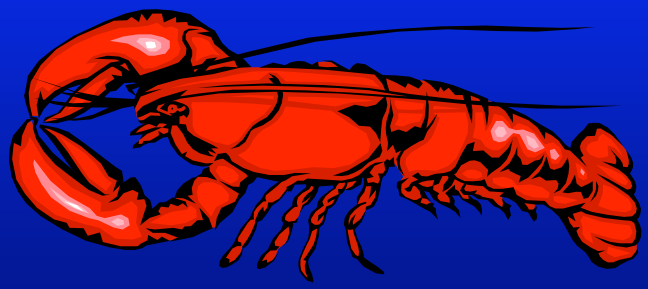




In 7th year of implementing "HPC" through the use of Quality Assurance specs

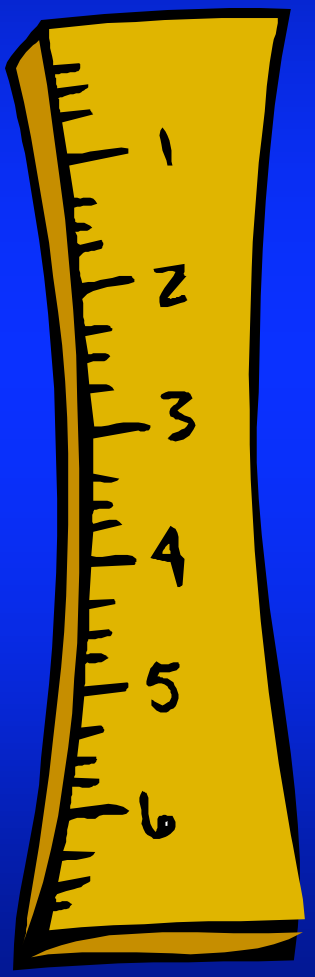
Maine's Modified QA Concrete Specification

- QA principles
- Some PWL pay factor (all in Fall '04)
- Retain some method spec principles
- Aggressive QC requirements



Common Measurables

- Strength
- Air
- Cover
- Chloride Permeability
  - Link to cover in spec
- w/c ratio



Some Non-measurables

- Curing
- Cold weather practices
- Hot weather practices
- Consolidation
- Stockpile management
- Workmanship

Quality Assurance for Concrete --Issues--

- Non-measurables; impact on quality
- Industry issues
- Statistical strength and permeability issues

Pay Factors

- Permeability
- Air
- Strength

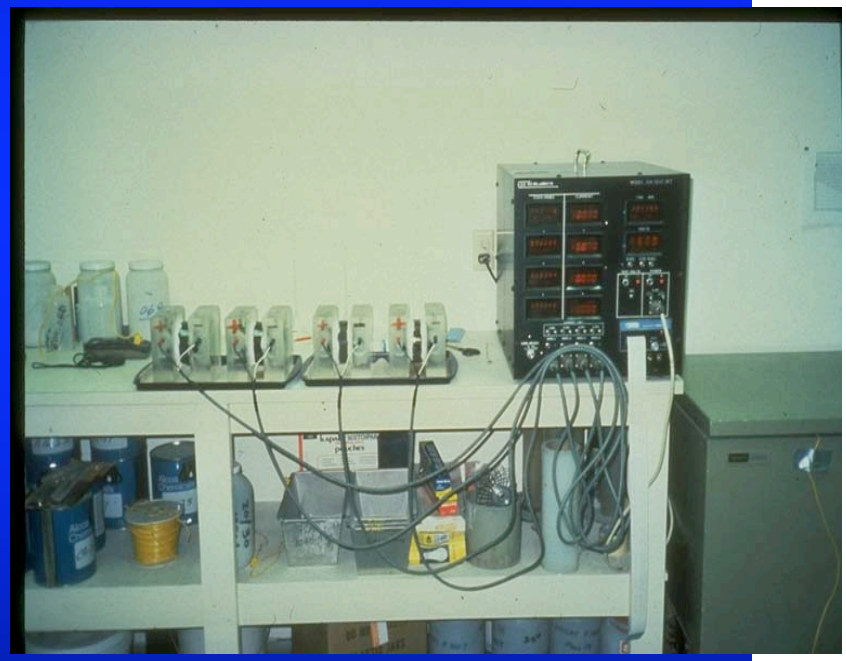
- Fall 2004: Composite pay factor
  - 40% permeability, 40% air content, 20% strength

Current Strength Spec

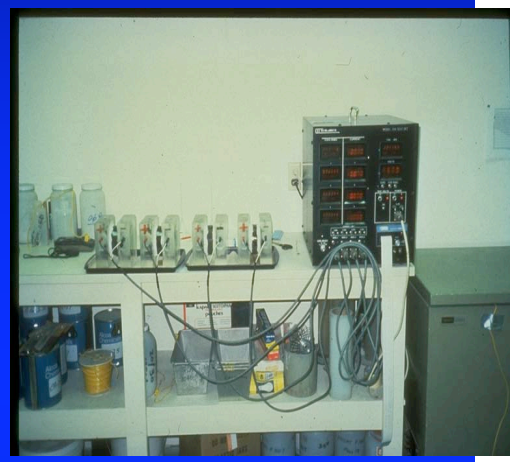
- Statistical strength analysis- per ACI
  - Avg. of 3 tests within 150 psi of f'_c or 1 test 200 psi below f'_c = remedial action
  - Pay factor is not PWL, linear based on avg. f'_c
  - No positive pay adjustment

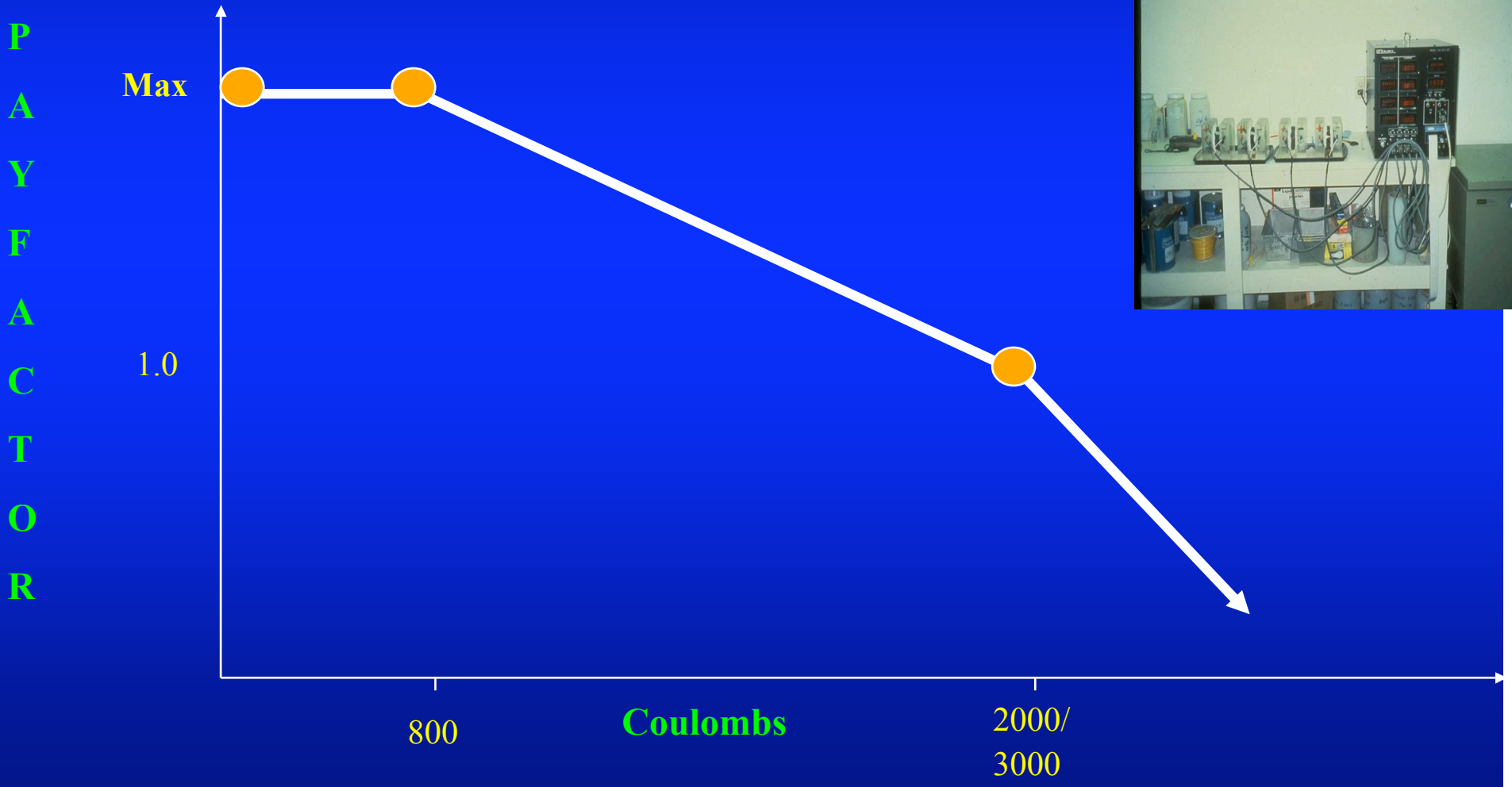
Current Permeability Spec
--AASHTO T-277--

- 7.5% or 5% max. bonus for permeability
  - HPC criteria
- Test @ 56 days unless >10% fly ash, then up to 120 days
- Average of two tests per sublot



Permeability Pay Factor





Air Content

- 2.5% max. bonus for air
- PWL calculation

Mix Design Approval

- Permeability trial batches
- Gradation limits
- ASR remediation
- Deleterious aggregate test
- Coarse aggregate absorption
- Limit pozzolan content
  - 30% fly ash; 50% slag
- Limit total cementitious content (660#/yd^3)

Typical Mixes

- Class A (structural)

330# Type II cement
330# GGBFS
1200# Fine agg.
1800# Coarse agg.

- Class LP (overlays, sidewalks, etc.)

318# Type II cement
318# GGBFS
10 to 25# silica fume
1200# Fine agg.
1800# Coarse agg.

MDOT Specification

- Attempts to address workmanship
  - Surface tolerance
  - Finish
- Evaporation rate for flatwork
  - 0.1 #/sf/hr to start
  - 0.15#/sf/hr = remediation per QC Plan

MDOT's QC Plan

- Submitted prior to any construction of QA items
- Includes all the items in the traditional plan

PLUS

- Contractor's method of complying with specs for non-measurables that significantly affect quality
- Significant financial penalties for violating QC Plan

What Has Maine Done and Learned?

- If QA specs are used, appropriate attention must be paid to the non-measurables
- Detailed QC Plans with monitoring are a must
- Statistical analysis can be a hard sell with industry

The End