Matching the Process to the Waste by Appropriate Testing:

A Guide for Thermal Desorption Projects

TMTS

Testing Before Toasting

- **Thermal desorption is widely utilized for Superfund and other organic-contaminated soils**
- **Thousands of tons of soil have been processed**
- **Hundreds of sites have been cleaned up**

But

- **Significant and costly $$$ mistakes are still made in bidding and executing these projects**

Primary Reasons for Mistakes in Bidding and Execution are:

- Appropriate data lacking, tests not run to define contaminated soil properties

or

- Available data was not utilized or compared to process limitations

Connecting Lab Tests with Full Scale Ops

- **This paper links lab tests and treatability studies with success and failure of full-scale treatment systems**
- **Low cost lab testing at the front end can save the site owner/PRP and/or the thermal treatment service contractor a lot of money – and grief – on the back end**
- **There are two levels of tests:**
  - **Standard lab tests, which use small (typically 1-gram) samples**
  - **Larger scale treatability tests, usually in a muffle furnace or pilot scale desorber**

Testing Approach

- **Use standard tests which are both inexpensive and dependable**
- **Some tests can be used quantitatively:**
  - **Heating value can be used to calculate:**
    - **Auxiliary fuel required**
    - **Amount of feedstock dilution required if organic concentrations are too high**
  - **Moisture content can be used to predict:**
    - **The amount of drying agent required to reduce the moisture content below the plastic limit and the MC at maximum Proctor Density to make material handling easier**
    - **The amount of desorber fuel required and capacity**

Testing Approach

(Continued)

- Results can also be used to make <u>qualitative</u> judgments:
  - Material handling equipment and processes
  - Type of thermal desorber (co- vs. counter-current)
  - Type of air pollution control equipment
  - Be aware that the tests detailed in this paper are not the typical EPA SW-846 8000 series tests used to assess hazardous constituents for regulatory purposes
  - Rather, they are <u>primarily ASTM test protocols</u> used to produce engineering data to match the waste and the process
- Choose labs with experience!

Example of the Gap between EPA/ASTM Tests:
Prentiss Creosote Project

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EPA vs. ASTM Test Results

- **The problem: Traditional "EPA" organic tests routinely understate the amount of organic contaminant in a soil**

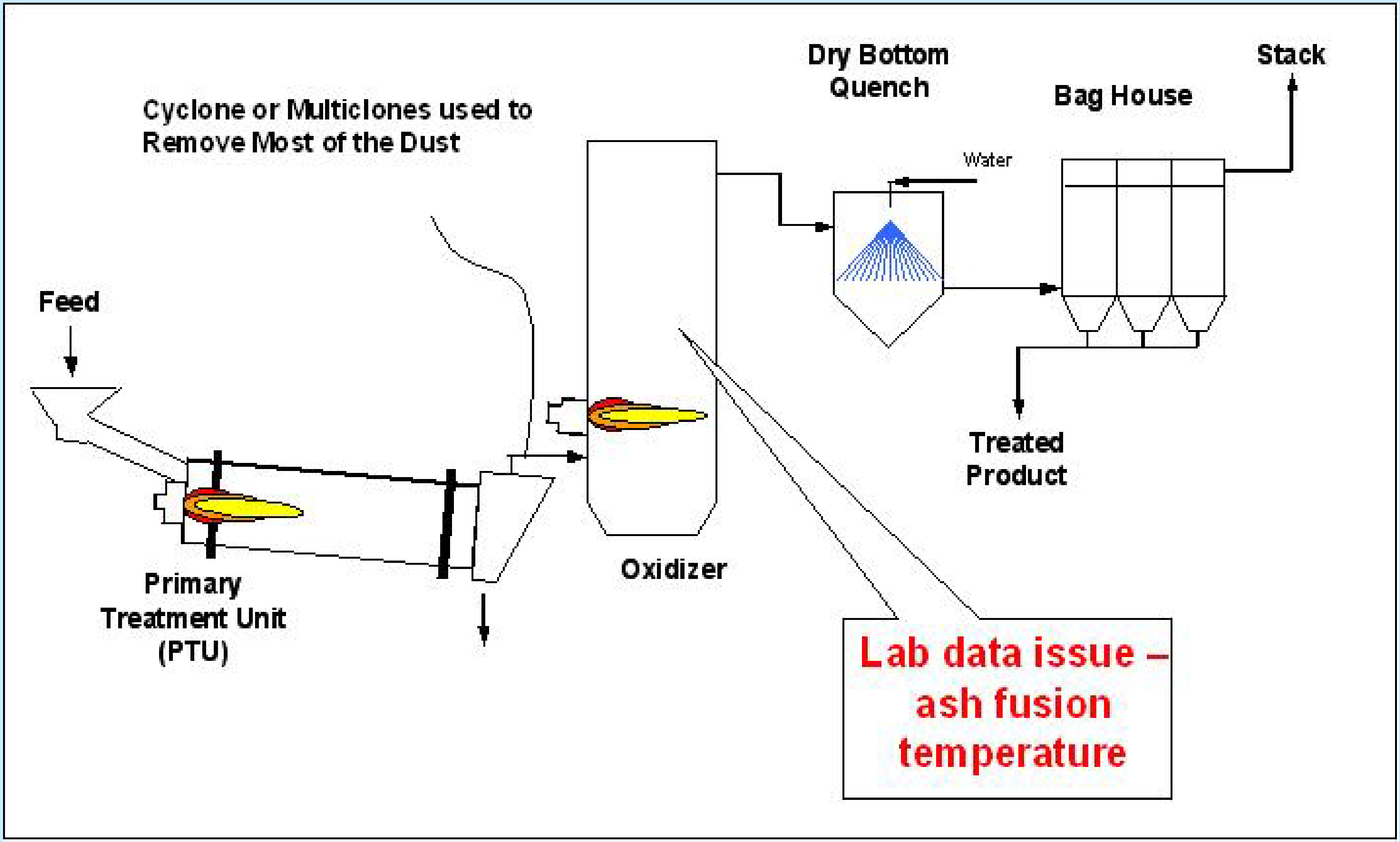
- **At Prentiss, coal tar PAH via EPA GC method totaled 6,240 ppm, or 0.624%**

- **The ASTM calorimeter test found 1,148 Btu/lb (638 cal/g). Using 17,000 Btu/lb (9,440 cal/g) for coal tar PAH compounds yields a figure of 68,000 ppm or 6.8%, more that 10 times greater than found by the EPA method**

EPA vs. ASTM Test Results
(Continued)

- **Why the gap?**
  - **Extraction/recovery issues**
  - **Molecular weight of compounds too high or low for GC**
  - **Other materials (e.g., cellulosic material, coal) in the waste which will not be accessed by the test method**
- **Bottom line: Decisions concerning system capacity and safety (LEL) should not be based solely on the results from EPA test methods for identifying individual organic compounds**

Cocurrent Thermal Desorber PFD



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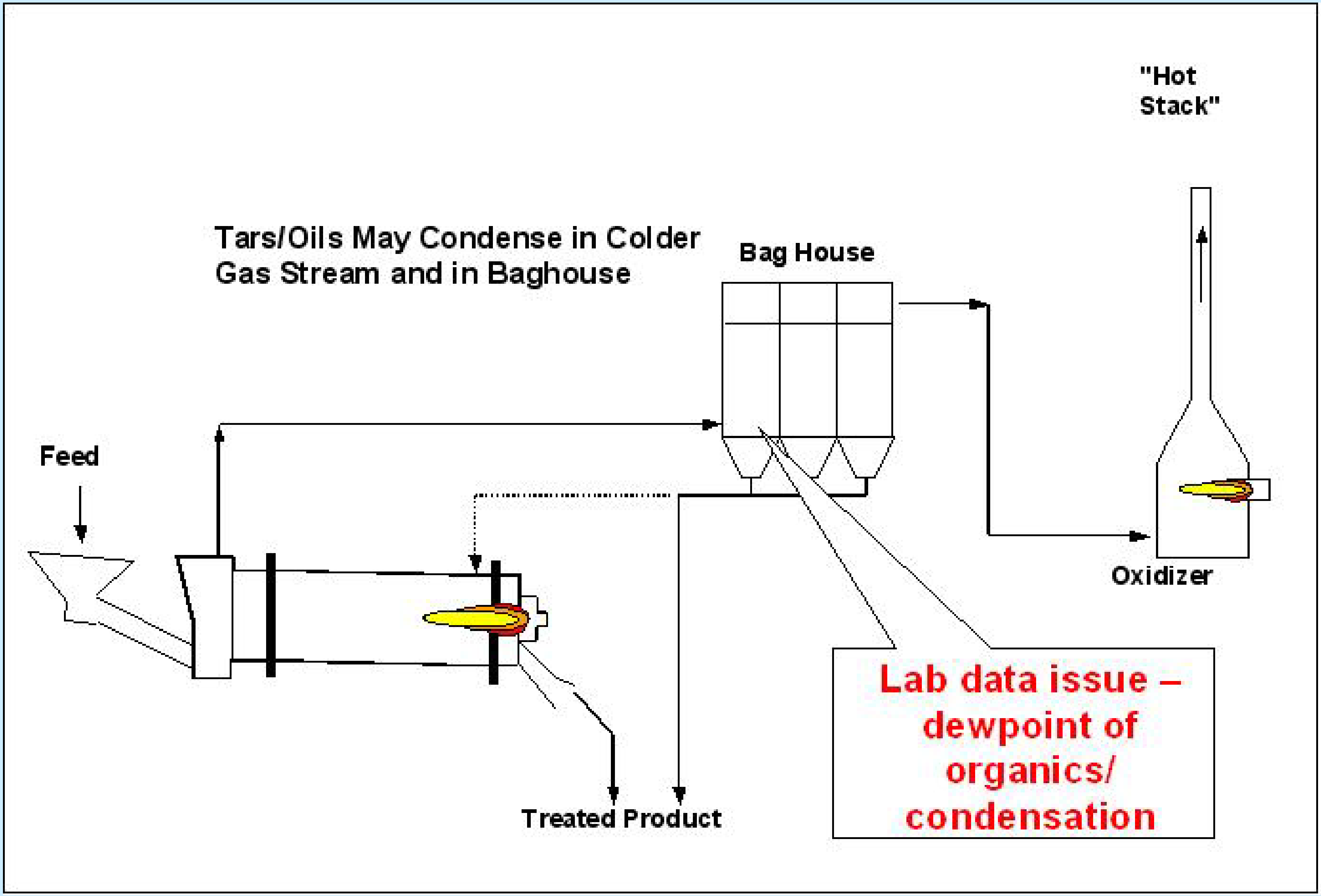
Cocurrent Thermal Desorber

Courtesy: ASTEC, Inc.

Countercurrent Thermal Desorber PFD



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Soil Parameters and Process Design/Operation Issues

Parameter	Design/Operation Issues
Organic concentration	Safety and capacity estimation
Organic boiling point	Ability to produce clean soil/dictates soil product temperature Preventing condensation in the baghouse on countercurrent systems
Soil matrix (e.g., sand, silt, clay, gravel) and particle size	Material handling, feed prep, and soil cooling and consolidation, APC
Soil moisture content	Material handling, capacity, fuel cost
Chemical compounds	Scrubber may be required for Cl & S May trigger dioxin testing Affects regulatory costs and reagent $

Civil Eng/Soil/Bulk Property Tests

Test Method/Comments	Effect on Design/Operation
Screen Fractionation (particle size) - ASTM D410	Defines type of air pollution control system required and type of pugmill mixer for cooling and consolidation
Bulk Density - ASTM D292	For jobs bid on in-place cubic yards, to convert to mass basis for costing; sizing of conveyors/bins
Atterberg limits	Feed system design; need for predrying via quick lime
Proctor Density	Required if product soil is to be backfilled and compacted for future use

Based on Screen Fractionation, a Fine Soil May Require a Baghouse for APC

In Florida, Sandy Soil Allowed use of a Low pressure Drop Venturi Scrubber

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Pugmill for Soil Cooling and Dust Control

Courtesy: ASTEC/SPI

Single Arm OK for Coarse Soil

Courtesy: ASTEC/SPI

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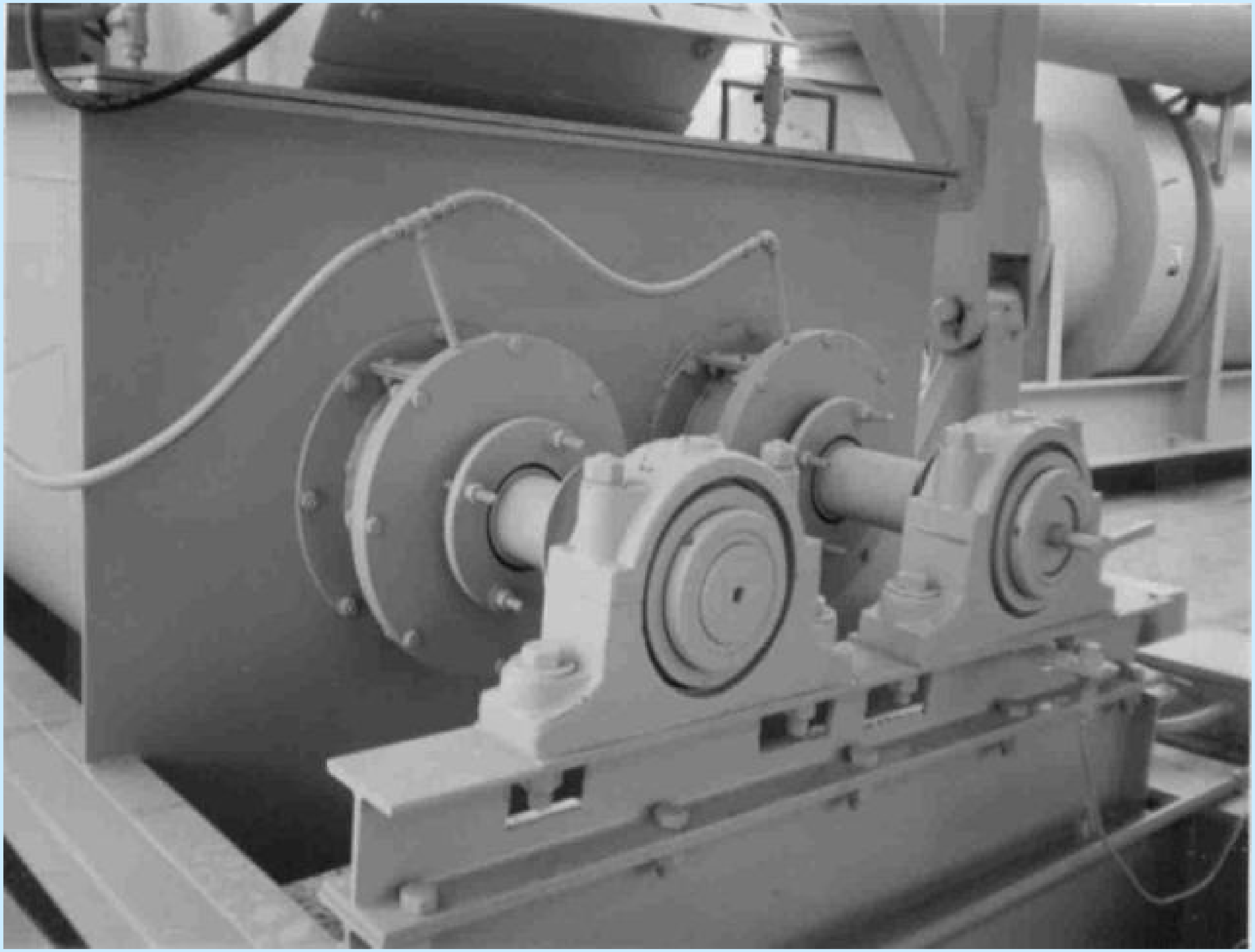
Double Arm Pugmill Better with Clays and Silts



 Courtesy: ASTEC/SPI

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Tests Methods – Combustion Series

Test Method/Comments	Effect on Design/Operation
Higher Heating Value - ASTM D1989 calorimeter	LEL/safety, maximum capacity, fuel use in oxidizer
Moisture Content - Gravimetric@105 C (not required if D5142 is done)	Capacity, fuel cost, need for lime pretreatment
ASTM D5142 Proximate, for mc, vm, fc, ash, at 950ºC	Volatile material (vm) and ash can be used to infer upper limit of organic content
ASTM D3176 Ultimate Analysis modified, for C, H, N, Cl, S, O by difference, ash, mc	Carbon and hydrogen can be used to infer organic content in the absence of carbonates; S and Cl, if organic, have impact on scrubbing costs
Ash Fusion Temperature - ASTM D1857 (oxidizing and reducing)	Required for clays and silts with sodium and potassium with cocurrent desorbers with horizontal oxidizer

Test Methods - Combustion Series

(Continued)

Test Method/Comments	Effect on Design/Operation
Ash Content - ASTM D5142 (or as part of proximate)	Set upper limit of organic content; product conveyor sizing
TGA/DSC (Thermo gravimetric analysis, differential scanning calorimetry)	Provides feedback on temperatures required to drive off organics
ASTM D3174 (run at 550°C rather than 750°C) or EPA 160.4 TVS/LOI for water samples/ sewage sludge (which can also be used for soils)	If correlated well with organic content, cheap/fast method to estimate organic content/fuel value in the field. LOI test temp can be matched to projected soil outlet temp.

Tests Methods – Combustion Series
(Continued)

Test Method/Comments	Effect on Design/Operation
Elemental Analysis - ASTM D2795, SiO_2, Al_2O_3, Fe_2O_3, TiO_2, P_2O_5, CaO, MgO, Na_2O, K_2O	Adds to information from ultimate analysis, and on potential for fluxing and slagging
Major and Minor Elements in Ash - D3862	If slagging is a concern in oxidizer
Trace Metals Analysis - ASTM D3863	If RCRA metals are an issue

Test Methods - Combustion Related and Acid Gases

Test Method/Comments	Effect on Design/Operation
TOC, total organic carbon in soil, EPA 9060;Walkley-Black (optional)	May correlate with organic content
Total recoverable petroleum hydrocarbons TRPH - method 418.1/Method 1664 (optional)	May correlate with organic content, cheap/fast method
Oil&Grease, similar to TRPH hydrocarbons (optional)	May correlate with organic content, cheap/fast method
Total org Cl (Optional if chlorine is known to not exist). ASTM D-808, D-4327, by difference	Dictates amount of caustic/lime to neutralize HCl; dictates material of construction for quench
Total organic sulfur (Optional if sulfur is known not to exist) (Requires inorganic and total to find organic fraction)	Dictates amount of caustic/lime to neutralize SO_2; dictates mtl of construction for quench

How Many/What Tests to Run?

- The slate of tests ultimately dictated by experience of personnel involved and knowledge of the waste on the site/site history
- Need for test ranges, e.g.:
  - Sandy soil with petroleum contamination, to
  - Uncontrolled Superfund dumpsite with fine clays and silts, organics and inorganics

Quantitative Use of Test Data

- **In a perfect world: Heating value, LOI, TOC, TPH/Oil&Grease, and GC all agree**
- **For example, dry sand, spiked with a 5% diesel fuel:**
  - **Heating value 0.05 x 19,567 = 978 Btu/lb (544 cal/g)**
  - **TPH/Oil&Grease would be 5%**
  - **LOI would be 5%**
  - **TOC would be 5% x 0.864 (the carbon fraction in diesel) = 4.3%**

Quantitative Use of Test Data

Real World Problems

- Clays with water of hydration (comes off > 105°C MC test temp), LOI will be higher than 5%
- Soils with carbonates may show higher LOIs if CO_2 is released at the test method's temperature.
- If elemental carbon exists, when added to that in spiked diesel, will yield TOC higher than 4.3%
  - Heating value will also be higher
  - However, in the process, carbon will not volatilize and will not enter a thermal desorber's oxidizer

Quantitative Use of Test Data

Real World Problems (Continued)

- **Soil with cellulosic material will add carbon to that of the spiked diesel, and produce TOC higher than 4.3%**

  - Heating value will be also be higher

  - In the process, up to 80% of the volatile matter in the cellulosic material will volatilize and enter the oxidizer of a thermal desorber

  - The fraction depends on product temp & part. size

- **Soils with heavily chlorinated organics will show lower heating values and higher LOIs when compared with petroleum-contaminated soils**

Quantitative Use of Test Data

Use Calorimeter as Touchstone

All that said:

- **The calorimeter results in Btu/lb or cal/g produce a <u>worst-case value</u> for the amount of organics that will be desorbed**
- **Many direct fired low-temp desorbers are limited to 2-2.5% vaporizable organic in feed, and some are limited to much lower values**
- **Compare calorimeter results to process limits as a starting point**

Quantitative Use of Test Data

Use Calorimeter as Touchstone (Continued)

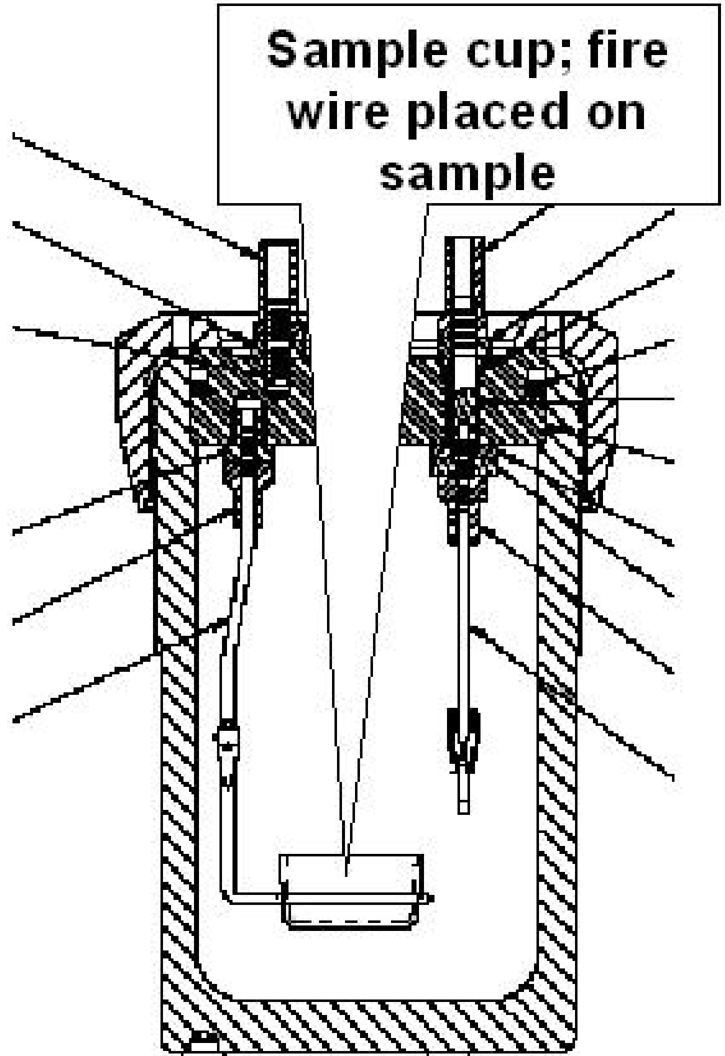
- **Can translate calorimeter results into vaporizable organic fraction to compare with process limits such as heat release in the oxidizer.**

- **The vaporizable organic fraction can also be used to assess compliance with NFPA 25% LEL safety limit for gases entering the oxidizer**

- **If organic concentrations > allowable, use results to estimate the amount of feed dilution required and the extra cost to process the material**

Calorimeter Vessel and Internals

Temp rise of external water jacket is translated into Btu/lb



Note: Use mineral oil or benzoic acid to boost soils with less than 2000 Btu/lb heating value

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Quantitative Use of Test Data

Use Calorimeter as Touchstone (Continued)

- **Calculating the amount of heat release in the oxidizer from the vaporizable organic fraction in the soil example follows:**

  - Soil 2.5% vaporizable petroleum-based organic

  - Feed rate of 40 tph

  Heat release 0.025 x 20,000 Btu/lb x 40 tph x 2000 lb/ton = 40 MM Btu/hr (42 kJ/hr)

Quantitative Use of Test Data

Use Calorimeter as Touchstone (Continued)

- **The oxidizer must be able to handle this load**
- **It may require separate control of burner fuel & air to allow:**
  - **Running at low burner fuel input and high excess air to burn all of the vaporized organics**
  - **Preventing shutdowns due to exceeding temp high-limit control**

Larger Scale Tests

- For new, unusual soil matrix or wastes, oven and pilot scale tests are sometimes run
- Sometimes used on big jobs to decrease risk
- Major question that these tests are used to answer is: How hot is hot enough?
- They yield qualitative data, not an exact replica of full scale operation

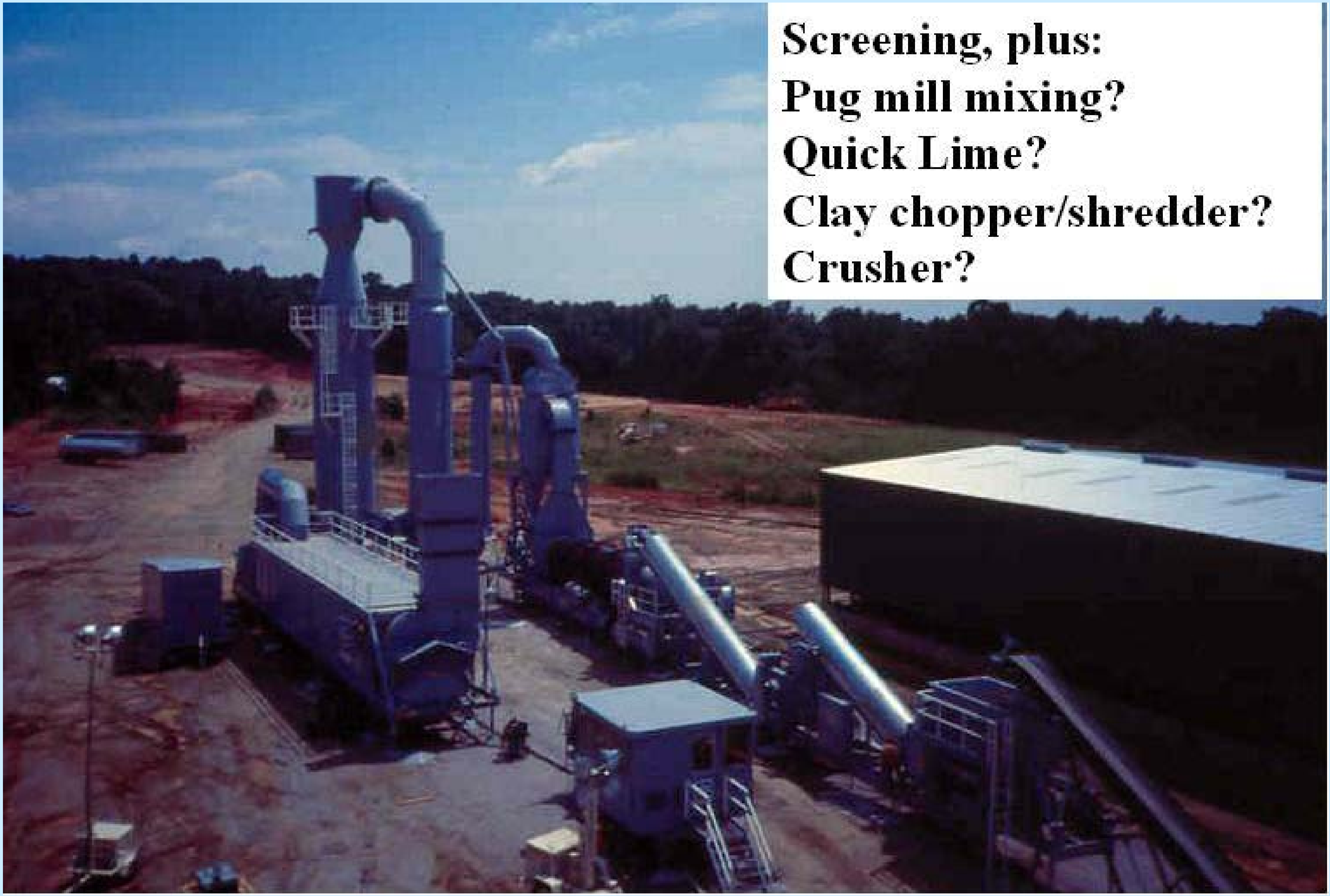
Test Oven and Trays for Treatability Test

Courtesy: Williams Environmental Services

Thermal Desorption Pilot Plant

Courtesy: Williams Environmental Services

Feed Prep Required Based on CE/Soil Test



Screening, plus:
Pug mill mixing?
Quick Lime?
Clay chopper/shredder?
Crusher?

Courtesy: Envirotech Mid Atlantic

For High Concentrations of Organics

- Indirectly heated retorts with condensers (e.g., for oil-based drilling mud)
- Paddle dryers, heated screws
- Paddle dryer + retort
- Direct-fired desorber with product recycle
- Have to run costs to see what works best!

Remember Run the Right Tests – So you Don’t Get Stuck!