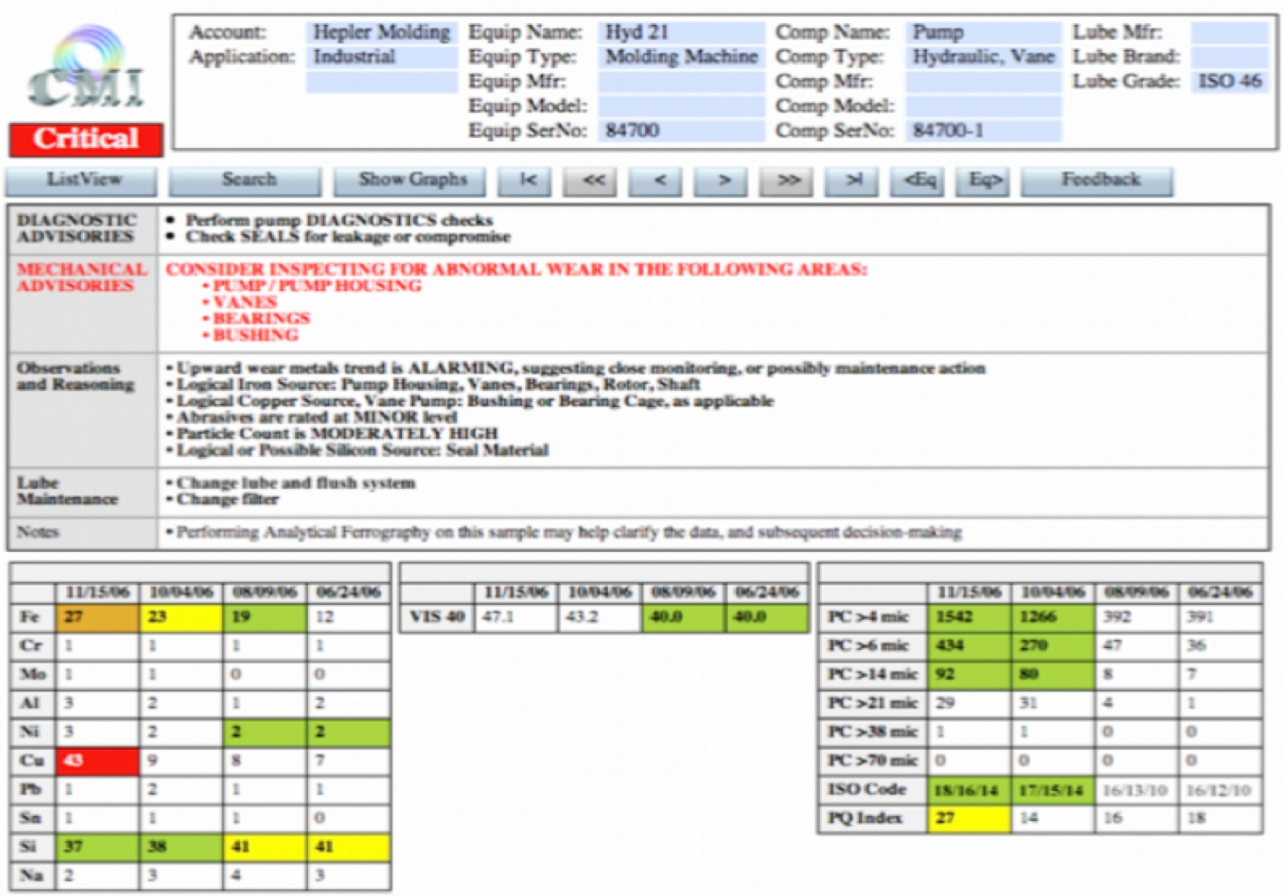
21st Century Fa Overviews, Vol. 1
Intelligent Agents (IAs) emerge to render *best Fa advisories*



Critical

Account:	Hepler Molding	Equip Name:	Hyd 21	Comp Name:	Pump	Lube Mfr:	
Application:	Industrial	Equip Type:	Molding Machine	Comp Type:	Hydraulic, Vane	Lube Brand:	
		Equip Mfr:		Comp Mfr:		Lube Grade:	ISO 46
		Equip Model:		Comp Model:			
		Equip SerNo:	84700	Comp SerNo:	84700-1		

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DIAGNOSTIC ADVISORIES	• Perform pump DIAGNOSTICS checks • Check SEALS for leakage or compromise
MECHANICAL ADVISORIES	CONSIDER INSPECTING FOR ABNORMAL WEAR IN THE FOLLOWING AREAS: • PUMP / PUMP HOUSING • VANES • BEARINGS • BUSHING
Observations and Reasoning	• Upward wear metals trend is ALARMING, suggesting close monitoring, or possibly maintenance action • Logical Iron Source: Pump Housing, Vanes, Bearings, Rotor, Shaft • Logical Copper Source, Vane Pump: Bushing or Bearing Cage, as applicable • Abrasives are rated at MINOR level • Particle Count is MODERATELY HIGH • Logical or Possible Silicon Source: Seal Material
Lube Maintenance	• Change lube and flush system • Change filter
Notes	• Performing Analytical Ferrography on this sample may help clarify the data, and subsequent decision-making

	11/15/06	10/04/06	08/09/06	06/24/06
Fe	27	23	19	12
Cr	1	1	1	1
Mo	1	1	0	0
Al	3	2	1	2
Ni	3	2	2	2
Cu	43	9	8	7
Pb	1	2	1	1
Sn	1	1	1	0
Si	37	38	41	41
Na	2	3	4	3

	11/15/06	10/04/06	08/09/06	06/24/06
VIS 40	47.1	43.2	40.0	40.0

	11/15/06	10/04/06	08/09/06	06/24/06
PC >4 mic	1542	1266	392	391
PC >6 mic	434	270	47	36
PC >14 mic	92	80	8	7
PC >21 mic	29	31	4	1
PC >38 mic	1	1	0	0
PC >70 mic	0	0	0	0
ISO Code	18/16/14	17/15/14	16/13/10	16/12/10
PQ Index	27	14	16	18

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The Fa Evaluation Challenge

- **Skilled Fa evaluators are retiring and expertise is being lost, as in many industries**
- **Remote evaluators often have a limited view of component history, parts composition, service application, etc.**
- **Wide variability in quality and content of interpretations**

Actual report from a well-known national lab !!

Observation: Fe and Cu are abnormally high
Recommendation: Identify source of high Fe and Cu levels

Using an Intelligent Agent to Evaluate (Expert System)

- **An Expert System does two basic things:**
  - **1. <u>Rates Data</u>** (Assigns a severity to the Data)
    - Limits
    - Trends, Acceleration
    - Moving Averages
    - Etc.
  - **2. <u>Renders Advisories</u> (The Fa Deliverable)**, usually based on rules and, if sophisticated enough, considers past history
- **Properties of a good Intelligent Agent**
  - Uses pattern recognition in addition to rules, including identification of persistent data combinations not previously vetted so that new rules can be created in priority fashion
  - Can be adapted to virtually any Component and Application
  - Addresses both the Machine and the Lubricant
  - Can be collaborative to receive new knowledge and update existing knowledge
  - Can vet its advisories, given appropriate feedback

EVALUATION
Precision Data Rating
1st Challenge for Intelligent Agents

Ensure that data are correctly assessed as to their significance in order to draw the correct conclusion and sense of urgency

What's Needed:

- **Statistics for each test to determine operating limits**
- **Normalization for time or distance and make-up**
- **Excursion trending beneath limits to spot movement; general trending to augment severity**
- **Consideration for the application and environment**
- **Flagging of data to indicate relative severity at several levels, setting the stage for for auto-commentary algorithms to be invoked:**

Severity	1	2	3	4
Data	NOTABLE	ABNORMAL	HIGH	SEVERE

Calculating and Setting Limits

	Low	High	Median	Avg	Std.Dev	1-sigma	2-sigma	3-sigma	6-sigma
Fe	8	156	42	54	20	74	94	114	174
Cr	0	30	3	4	5	9	14	19	34
Al	0	43	5	7	9	16	25	34	61
Cu	5	104	17	20	11	31	42	53	86
Pb	4	88	10	12	9	21	30	39	66

- **BE SURE TO CONSTRAIN THE DATA POLLED PROPERLY**
- **PREFER TO USE SITE'S DATA IF SUFFICIENT POPULATION EXISTS**
- **NEWER DATA ARE MORE IMPORTANT THAN OLDER DATA**

Factored Trending

more realistic, credible movement measurement

Previous Value Range		Factor	Pivot DELTA	Final Factor	Flag Point FROM MaxValue
>5	10	3	0.50	1.5	26
MIN >10	25 MAX	1.2	0.50	0.6	41
>25	45	1	0.50	0.5	69
>45	80	0.9	0.50	0.45	117
>80	120	0.8	0.50	0.4	169

For this component, a range from 26-45 is 'typical', representing the crest of a typical distribution curve. When a value falls above or below this range it must be treated as somewhat deviant, i.e., allowable changes (trending) must be compressed or expanded, consistent with the datum's relative position in the group distribution. A factor can be developed, based on a curve with several plot points specified, as per above, such that excursions are viewed proportionally.

EVALUATION
Strong Maintenance Advisories
2nd Challenge for Intelligent Agents

There is no Evaluation unless an Advisory is rendered…

What's Needed:

- **In-depth comments with subtle nuances**
- **Advisories fired consistently, with complex algorithms for appropriate differentiation**
- **Advisories that are correctly phrased and sequenced for easy understanding and decision-making**

- **A mechanism for acquiring Feedback as to maintenance performed (or *not*) and advisory verification, simultaneously creating hard data for program gains assessment**

EVALUATION
Hierarchical Interpretive Depth
- Intelligent Differentiation -

Equipment houses the Component

Component houses the lubricant (Component Type Required)

- Equipment Type **(Haul Truck, Plant, Marine Vessel, …)**
  - **Equipment Mfr and Model**
- *Component Type* **(Gearset, Hydraulic, Gas Turbine, …)**
  - **Mfr**: **CAT** (basic metallurgy knowledge)
    - **Model**: **3408E**
      (more specific component knowledge and data rating)
      - **Application** (Industrial, Off-Road, Oil & Gas, …)
        - **Wild Card** (any further differentiation that is needed)
- Lube Mfr and Brand **(*Mfr useless by itself*)**
- Lube Grade **(Program can propose, if missing)**
- Filter Type **(Centrifugal, By-Pass, None)**
- Filter Mfr and Brand
- Filter Micron or Beta Rating

EVALUATION
Tables of Boundaries (TOB)
The more Control and Managing tools, the better…
Caveat: Better be confident when tweaking

TOB Name				TOB Key	34							Account Number	(Null)							
App Type	OFF-HIGHWAY			App Sub Type	(Null)							Lube Mfr	(Null)							
Equip Type	(Null)			Comp Type	BBF - GEAR, Final Drive							Lube Brand	(Null)							
Equip Mfr	Volvo			Comp Mfr	(Null)							Lube Grade	(Null)							
Equip Model	A35D			Comp Model	(Null)															
Save	Calculate	Select All	Unselect All	Close																

	Result	Lo Lim	Hi Lim	L%C	H%C	L%A	H%A	MED	AVG	Sigma	Pop	Range	POS Sev				POS Sigma Factors				AGG
													1	2	3	4	1	2	3	4	
	Fe	0	199		50		35	37	75.73	102.89	1284	805(886)	199	323	436	693	1.20	2.40	3.50	6.00	
☑	Fe - New	0	299		50		35	37	75.73	102.89	1284	805(886)	299	485	654	1040	1.20	2.40	3.50	6.00	1.50
	Cr	0	5		50		35	1	1.45	2.25	1284	11(11)	5	9	15	24	3.45	6.21	10.34	16.55	
☑	Cr - New	0	4		50		35	1	1.45	2.25	1284	11(11)	4	7	12	19	3.45	6.00	10.34	16.55	0.80

Negative severity is available, but normally not applied to wear metals.

Standard statistical approaches are used, although the stats are nuanced against experience and other influential input.

There were 1284 samples from which to draw, making these numbers highly vetted.

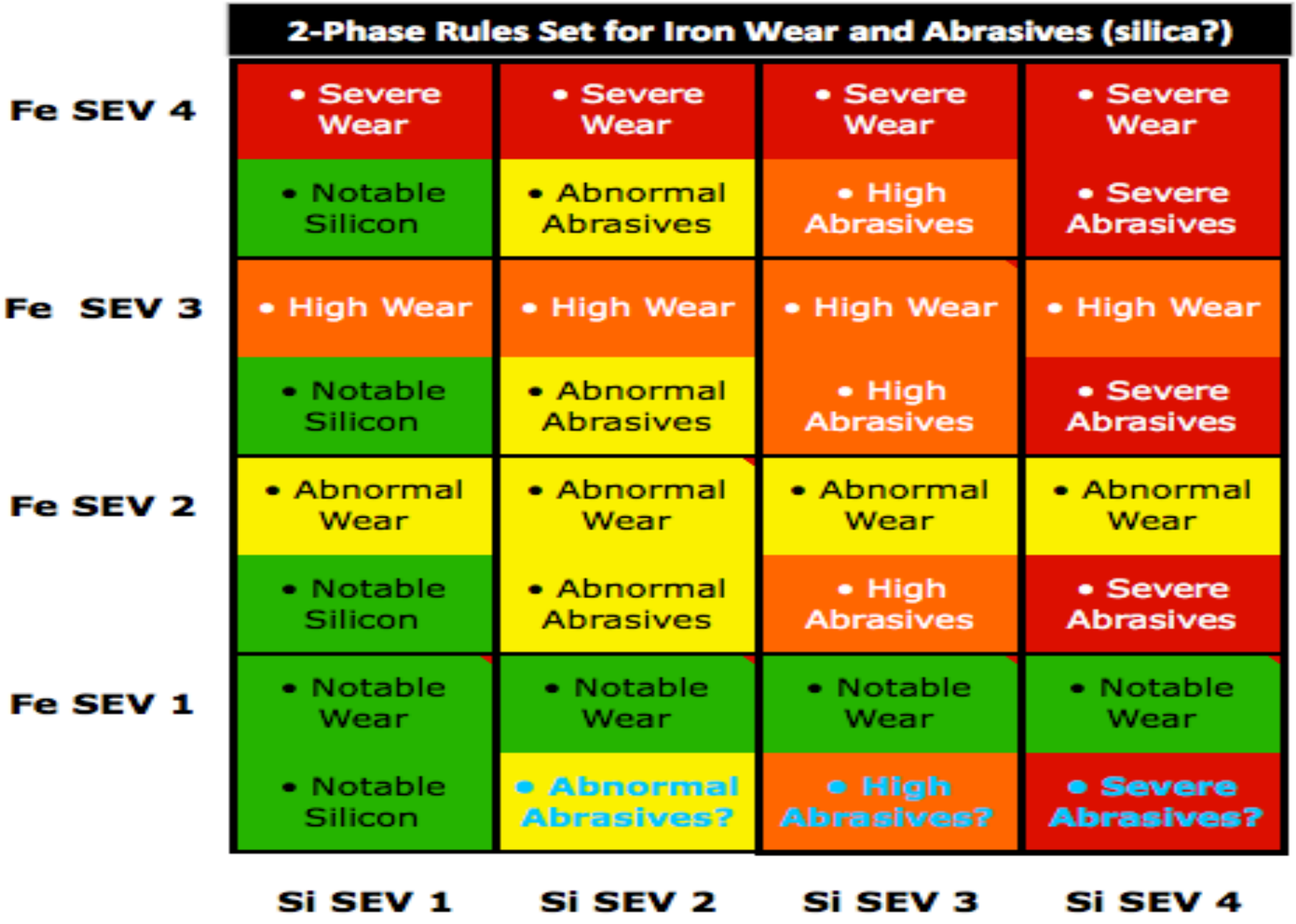
A proprietary algorithm is used to make such decisions.

There was at least one outlier at 886ppm Iron, that was excused from the stats, once identified.

Individual Accounts will usually need customized TOBs, based on their data in their Application and Environment

“”Aggressiveness”” overrides, or individual Sigma factor changes for a flagging table are possible. Granularity is often very important in assessing (rating) data

EVALUATION
2-Phase Rule for Fe & Si (Wear vs. Abrasives?)



Takeaway Summary

Fa now has real time parity with any CM aspect, including Vibration and Ultrasound gaining traction at the turn of the 21st Century

- **Tier 1 = Online – at the machine (real time)**
- **Tier 2 = Onsite – near the machine (growing fast)**
- **Tier 3 = Offsite – remote testing**

With all the data sensors provide, coupled with ever-increasing complexity of machinery and lubricants, an Intelligent Agent is essentially a necessity to best assess machine condition and render advisories