Ceramics Knowledge Platform - Comprehensive Plan

A vision for preserving, exploring, and advancing ceramics knowledge

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The Vision

Build a comprehensive ceramics knowledge and calculation platform that:

- Consolidates scattered ceramics data into one authoritative place
- Provides Insight-Live caliber calculations and tools
- Makes complex chemistry accessible to all potters
- Preserves knowledge for future generations
- Grows and improves over years of development

Data Foundation

Current Data Sources

- **DigitalFire.com raw HTML**: ~800MB, 7,730+ pages of authoritative ceramics knowledge
- **Structured exports**: 2,343 materials, 96 recipes, hazards, glossary, schools, oxides
- **20,000+ ceramic recipes**: To be imported and analyzed
- **Legacy collections**: 1990s TXT files and glaze databases to be preserved

Data Types

- Materials with oxide analysis
- Recipes with ingredients and chemistry
- Hazards and safety information
- Glossary terms and definitions
- Schools and educational programs
- Articles and technical documentation
- Pictures and visual references
- Tests and procedures

- Firing schedules

Core Features (Priority: Now)

1. Modular Architecture

- Plugin registry for easy feature additions
- Feature flags to enable/disable capabilities
- Self-documenting codebase for long-term maintenance
- Separate packages: parsers, storage, calculators, search, AI, UI
- Designed for years of growth and improvement

2. PostgreSQL Database

- Comprehensive schema for all content types
- Data provenance tracking (where each record came from)
- Source attribution (DigitalFire, legacy collections, contributions)
- Confidence levels (well-tested vs unverified)
- Version history for tracking changes
- Relationship tables linking materials, recipes, hazards

3. Robust Import Pipeline

- Batch upload with progress tracking
- Legacy format parsers (90s TXT, CSV, old glaze software)
- Format auto-detection
- Duplicate detection across sources
- Merge assistance for combining partial records
- Provenance tracking
- Progress resumption if interrupted
- Incremental parsing (add new data without re-processing everything)

4. Ceramic Chemistry Engine

Core Calculations (Insight-Live style):

- Unity formula (RO, R2O3, RO2 unity)
- Thermal expansion with customizable oxide factors
- LOI (Loss on Ignition)

- Si:Al ratio and other critical ratios
- Oxide contribution calculator
- Flux balance analyzer
- Batch chemistry vs unity chemistry toggle

Key Principle: Every calculation includes "why" explanations so potters understand, not just compute.

5. Blend Calculators

- Triaxial blend calculator (3-corner experiments)
- Line blend calculator (2-material progressions)
- Quadraxial blend calculator (4-corner experiments)
- Volumetric blend converter
- Real-time chemistry updates as you adjust

6. Stull Chart Visualization

- Plot all 20,000+ recipes on the chart
- Heat maps showing recipe density
- Interactive zones (matte, glossy, crystalline regions)
- Click any region to find recipes there
- Overlay multiple recipes for comparison
- **Gap finder**: Identify unexplored chemistry territory
- Filter by cone, atmosphere, surface type

7. Recipe Optimization

- Target chemistry optimizer ("I want Si:Al of 10:1")
- Goal-based recipe generator ("Create a cone 6 glossy blue")
- Constraint solver (balance multiple requirements)
- Multi-objective optimization (cost, chemistry, safety)
- Substitution finder with chemistry matching
- Troubleshooting assistant (diagnose crawling, crazing, pinholing)

8. Search and Discovery

- Full-text search with PostgreSQL indexing
- Faceted filtering (cone, atmosphere, material type, surface)
- Pattern recognition across 20k recipes
- Similar recipe finder (chemically related)
- **"Find Everything About X"**: Comprehensive term exploration
- Terminology bridge across traditions (same concept, different names)

9. Relationship Graph

- Materials ↔ Recipes ↔ Hazards connections
- Network visualization
- Co-occurrence analysis (materials that work together)
- Cross-reference to authoritative DigitalFire sources
- Success pattern detection (what stable glazes share)
- Failure pattern detection (what problematic recipes share)

10. Material Intelligence

- Oxide contribution calculator (what does 5% more feldspar change?)
- Material purity variations (theoretical vs actual analysis)
- Batch chemistry vs unity chemistry toggle
- Raw material to oxide breakdown visualizer
- Material sourcing alternatives

11. Advanced Chemistry Tools

- Alumina:Silica ratio optimizer
- Flux balance analyzer (which fluxes dominate)
- Durability index estimation
- Thermal shock resistance prediction
- Surface tension estimation (crawling prevention)
- Melt fluidity/viscosity indices
- Glaze stability and crystallization heuristics

12. Quality Assurance

- Recipe validation against known limits
- Chemistry sanity checks (impossible combinations)
- Cross-reference verification
- Confidence scoring for parsed data
- Completeness analysis (what's missing?)
- **Mistake library**: Visual examples of common problems

13. Predictive Features

- Firing result prediction (given chemistry + schedule)
- Defect probability scoring before firing
- Glaze-body compatibility predictor
- Color outcome prediction with confidence levels

- Surface texture prediction (matte/satin/gloss from chemistry)

14. AI-Powered Intelligence

- Entity extraction (materials, temperatures, techniques from text)
- Semantic search (find by meaning, not just keywords)
- Natural language Q&A with source citations
- Auto-summarization of long articles
- Smart tagging and categorization
- Missing data prediction
- Inconsistency detection
- Relationship inference from text

15. Visualizations

- Oxide composition radar/spider charts
- Temperature range timelines
- Recipe clustering visualizations
- **Visual chemistry**: What high silica looks like vs low
- Durability and surface prediction displays
- Network graphs of relationships
- Print-ready outputs for studio use

16. Educational Features

- Learning paths (beginner → advanced glaze chemistry)
- Inline glossary with definitions
- "Compare and explain" showing chemistry changes
- Recipe walkthroughs with annotations
- Progression tracking (your journey as a potter)
- Interactive tutorials for unity formula and expansion
- Mistake diagnosis with visual examples

17. Export and Data Portability

- Multiple open formats (JSON, CSV, PDF)
- GlazeChem/Insight format compatibility
- PDF recipe book generation
- Shareable recipe links
- Test tile label generation
- Offline data snapshots
- **Never locked in**: Your data is always exportable

18. Potter-Friendly UX

- Quick lookup mode for studio use (fast, simple)
- Tablet-friendly with big touch targets (clay-covered hands)
- Glaze notebook feel (like a personal journal)
- Session persistence (favorites, search history)
- Graceful offline handling
- Print-ready outputs for kiln-side reference

Future Features (Priority: Later)

Historical & Archival

- Timeline of glaze development through history
- Traditional recipe preservation (ancient techniques)
- Attribution tracking (who developed what)
- Recipe genealogy (trace modifications over time)

Comparative Analysis

- Era comparison (how did cone 10 glazes evolve 1950-2020?)
- Regional style fingerprinting (Japanese vs European chemistry)
- Artist/studio signature detection
- Commercial vs studio recipe differences

Kiln & Firing Intelligence

- Firing schedule library
- Schedule recommendations based on chemistry
- Ramp rate impact analysis
- Atmosphere switching point suggestions

Safety & Compliance (Maybe)

- Full hazard chain analysis
- MSDS/SDS sheet generation
- Food safety assessment
- PPE recommendations per recipe

Community Features (Future)

- User contributions with validation
- Discussion threads on items
- Rating system for recipes
- Recipe versioning and forks

Design Principles

For the Working Potter

- Quick recipe lookup while at the wheel
- Glaze notebook feel - like a digital personal journal
- Studio-friendly - works on tablet with clay-covered hands
- Offline capability - studio might not have great internet
- Print-ready outputs - potters still use paper at the kiln

For Learning and Growth

- "Why" explanations - not just what, but why it matters
- Visual chemistry - show what changes look like, not just numbers
- Mistake library - "I got crawling, what went wrong?"
- Progression tracking - see your journey over time

For the Ceramics Community

- Preserve disappearing knowledge from older potters
- Bridge terminology gaps across traditions
- Accessibility - vision issues, languages, skill levels
- DigitalFire as authoritative reference - cross-link everything

For Longevity

- Data portability - export everything, never locked in
- Open formats - standard notation, common file types
- Self-documenting - explains itself to future maintainers
- Graceful degradation - works even if some features break
- Modular design - easy to add new features over years

Technical Architecture

Database Schema Design

Three-Schema Separation:

- `raw_ingest` - Unprocessed imported data, original HTML, source files
- `core` - Normalized, validated data (materials, recipes, relationships)
- `derived` - Pre-computed calculations, caches, aggregations

Provenance Fields (on every record):

- `source` - Origin identifier (e.g., "digitalfire", "legacy_txt", "user")
- `source_url` - Original URL if applicable
- `imported_at` - Timestamp of import
- `confidence` - Data quality score (0.0-1.0)
- `version` - Record version for history tracking

Units Handling Standards

Data Type	Storage Format	Display Flexibility
Recipe percentages	Decimal (0-100)	Show as %, convert to batch weights
Batch weights	Grams	Convert to lbs/oz on display
Molecular weights	g/mol (4 decimal precision)	Scientific notation
Temperatures	Celsius (integer)	Convert to Fahrenheit, show cone equivalents
Mesh sizes	Integer (mesh number)	Lookup table for micron equivalents

Specific gravity	Decimal (2 decimal precision)	e.g., 2.60
LOI	Percentage (2 decimal precision)	e.g., 12.50%
Expansion coefficients	Float with exponent	e.g., 7.5×10^{-6} (smart display)

Oxide Chemistry Master List

Oxide	Formula	Mol. Weight (g/mol)	Unity Group	Default Expansion ($\times 10^{-6}$)
Silica	SiO_2	60.0840	RO_2	0.035
Alumina	Al_2O_3	101.9600	R_2O_3	0.056
Boric Oxide	B_2O_3	69.6200	R_2O_3	-0.065
Lithia	Li_2O	29.8800	RO (flux)	0.270
Soda	Na_2O	61.9800	RO (flux)	0.392
Potash	K_2O	94.2000	RO (flux)	0.331
Magnesia	MgO	40.3000	RO (flux)	0.030
Calcia	CaO	56.0800	RO (flux)	0.163
Strontia	SrO	103.6200	RO (flux)	0.121

Baria	BaO	153.3300	RO (flux)	0.141
Zinc Oxide	ZnO	81.3800	RO (flux)	0.060
Lead Oxide	PbO	223.2000	RO (flux)	0.100
Iron Oxide	Fe2O3	159.6900	R2O3	0.090
Titania	TiO2	79.8700	RO2	0.055
Phosphorus Pentoxide	P2O5	141.9400	R2O3	0.090
Manganese Oxide	MnO	70.9400	RO	0.080

Note: Expansion coefficients are customizable per user and can be updated as new research emerges.

Relationship Types

Relationship	From Entity	To Entity	Properties
composition	Material	Oxide	percentage, loi_adjusted
ingredient	Recipe	Material	percentage, order, notes
hazard_link	Material	Hazard	severity, exposure_route
substitute	Material	Material	similarity_score, notes, chemistry_match
variation	Recipe	Recipe	change_description, parent_id

reference	Content	Content	context, link_type
defines	Glossary	Content	inline_position, term_variant
uses_temp	Recipe	Temperature	cone, celsius, atmosphere
atmosphere	Recipe	Atmosphere	primary, secondary
surface	Recipe	Surface	matte, satin, gloss, crystalline
source_link	Any	RawPage	source_url, extracted_from

Scientific Data Precision

Calculation Engine:

- Use Python `Decimal` for all chemistry calculations (avoid floating point rounding errors)
- Store full precision internally (up to 10 decimal places)
- Display 2-3 decimal places to potters (match practical measurement precision)
- Never imply false accuracy (respect significant figures from source data)

Confidence Scoring:

- 1.0 = Lab-analyzed, peer-reviewed data
- 0.8 = Authoritative source (DigitalFire, major suppliers)
- 0.6 = Community-verified, multiple confirmations
- 0.4 = Single source, unverified
- 0.2 = Legacy import, uncertain quality

Visualization Strategy

Library	Role	Best Used For
Pandas	Data engine	All calculations flow through DataFrames
Streamlit	UI framework	App shell, layouts, widgets, filters

Plotly	Interactive exploration	Stull charts, 20k recipe scatter, zoom/pan/hover
Altair	Declarative layered charts	Triaxial blends, multi-series, clean syntax
Matplotlib	Print/export quality	PDF recipe cards, high-DPI Stull charts for printing

Data Density Handling (20k+ recipes):

- Level-of-detail (LOD) rendering for large datasets
- Smart clustering at zoom levels
- Essential filter controls (cone, atmosphere, surface type)
- Hover details without overwhelming the view
- Progressive loading for performance

Data Contracts

Parser Output Contract:

```
{
  "url": str,
  "title": str,
  "content_text": str,
  "extracted_entities": {
      "materials": List[str],
      "temperatures": List[{"value": int, "unit": str}],
      "percentages": List[float]
  },
  "extracted_links": List[str],
  "category": str,
```

```
    "confidence_score": float,
    "parse_timestamp": datetime
}
```

Legacy TXT Parser Output:

```
{
    "recipe_name": str,
    "ingredients": List[{"material": str, "percentage": float}],
    "source_file": str,
    "parse_confidence": float,
    "format_detected": str
}
```

Calculation Engine Output:

```
{
    "unity_formula": {
        "RO": {"Na2O": 0.25, "K2O": 0.15, "CaO": 0.60},
        "R2O3": {"Al2O3": 0.45, "B2O3": 0.10},
        "RO2": {"SiO2": 3.80}
    },
    "expansion": float,
    "loi": float,
    "si_al_ratio": float,
```

```
    "flux_balance": {"alkali": float, "alkaline_earth": float, "other": float},
    "explanations": {
        "expansion": "Why this expansion value matters...",
        "si_al_ratio": "What this ratio indicates..."
    }
}
```

Indexing Strategy

Primary Search:

- PostgreSQL full-text search with `tsvector` columns
- GIN indexes for fast lookups

Fuzzy Matching:

- Trigram indexes (`pg_trgm`) for typo tolerance
- Material name aliases (EPK = Edgar Plastic Kaolin)

Future Semantic Search:

- Vector embeddings column (can add later)
- pgvector extension ready

Codebase Structure

```
/modules
  /parsers       - HTML extraction, legacy format import
  /storage       - Database models, repositories
  /calculators   - Chemistry calculations, blend tools
  /search        - Full-text, semantic, pattern matching
  /ai            - Entity extraction, Q&A, summarization
```

```
 /ui           - Streamlit pages, visualizations

/config

 feature_flags.json

 oxide_factors.json

/data

 feature_roadmap.json
```

Database Schema (Key Tables)

- `materials` - oxide analysis, properties, provenance
- `recipes` - ingredients, chemistry, calculations
- `oxides` - expansion factors, properties
- `hazards` - safety information
- `relationships` - material-recipe, material-hazard links
- `raw_pages` - original HTML with extracted entities
- `calculations` - cached unity, expansion, LOI results
- `quality_scores` - confidence, completeness metrics

Feature Flag System

- Enable/disable any feature via config
- Small updates: Add config values
- Medium updates: Add to existing module
- Large updates: Add new module following template

Update Size Categories

Small Updates (Config Changes)

- Add new oxide expansion factors
- Tweak calculation parameters
- Add new filter options
- Update terminology mappings

Medium Updates (Extend Existing Module)

- New calculator type in /calculators
- New visualization in /ui
- New search filter in /search
- New export format in export module

Large Updates (New Module)

- New AI capability
- New data source integration
- Major new feature area
- New external service integration

Legacy Data Preservation

The Mission

Ceramics knowledge is scattered across decades of files, databases, and potters' personal notes. This platform consolidates it into one searchable, analyzable, preservable place.

Legacy Import Capabilities

- 1990s TXT file collections
- Old glaze calculation software exports
- CSV recipe databases
- Various community formats
- Format auto-detection

Preservation Features

- Provenance tracking (original source)
- Attribution (who contributed)
- Version history
- Confidence levels
- Merge detection (same recipe, different sources)

Unique Opportunities with This Data

20,000+ Recipes Enables:

- Pattern detection no one has seen before
- Chemistry clustering and similarity analysis
- Success/failure pattern recognition
- Gap finding (unexplored chemistry spaces)
- Trend analysis across decades
- Recommendation systems based on goals

DigitalFire Authority:

- Cross-reference everything to authoritative sources
- Link explanations to original documentation
- Preserve the "why" behind the data

Combined Knowledge:

- Materials linked to recipes that use them
- Hazards linked to materials that contain them
- Glossary terms linked inline
- Related content suggestions

Long-Term Maintenance

Data Freshness

- Incremental update capability
- Version tracking for changes
- Differential updates (only process new/changed)
- Provenance for all records

Code Maintainability

- Self-documenting module structure
- Clear separation of concerns

- Feature flags for staged rollout
- Plugin pattern for new features

Sustainability

- Open formats throughout
- No vendor lock-in
- Exportable everything
- Clear documentation

Future Preservation Philosophy

This project aspires to be part of ceramics history itself - a digital artifact that future generations (human and AI) can understand, extend, and build upon.

Core Principles

- **Self-documenting**: Code and data explain *why*, not just *what*
- **Intent preservation**: Decisions are recorded with their reasoning
- **Human-readable first**: Formats that can be understood without special tools
- **No proprietary lock-in**: Open standards throughout
- **Active maintenance mindset**: Digital preservation requires ongoing care

Why This Matters

Just as R.T. Stull's 1912 paper still guides potters 112+ years later, this platform is designed to remain useful and understandable decades from now. The planning conversations, decision rationale, and historical context are preserved as part of the project's own history.

FAIR Principles

Following research software best practices (FAIR4RS):

Findable

- Persistent identifiers (DOIs via Zenodo for releases)
- Rich metadata following CodeMeta standards
- Indexed in searchable registries

Accessible

- Open repositories (GitHub + archive snapshots)
- Clear access protocols
- Long-term preservation via Software Heritage

Interoperable

- Standard data formats (JSON, CSV, YAML, Markdown)
- Open APIs
- Platform-agnostic architecture

Reusable

- Well-documented code with comments explaining the science
- Clear licensing (see Licensing Strategy)
- Version snapshots with DOIs
- Comprehensive dependency management

Future Preservation Standards

File Formats

- **Documentation**: Markdown (human-readable), PDF/A (archival)
- **Data**: JSON, CSV, YAML (open, non-proprietary)
- **Code**: Python with comprehensive comments

Persistent Identifiers

- **DOI**: Via Zenodo/Figshare for citable software versions
- **SWHID**: ISO/IEC 18670 Software Hash Identifier for source code

Archival Practices

- 3-2-1 backup rule (3 copies, 2 media types, 1 offsite)
- Archive snapshots to Software Heritage
- Checksums (SHA-256) for integrity verification
- Format migration every 3-5 years as needed

Metadata Standards

- CodeMeta for software discoverability
- CITATION.cff for citation information
- Comprehensive README explaining intent and architecture

Licensing Strategy

Multi-license approach to protect different aspects appropriately:

MIT License - UI & Utility Code

- Permissive, widely understood
- Allows anyone to use, modify, share
- Applied to: UI components, helper utilities, non-core modules

GPL v3 - Core Infrastructure (Forever-Open)

- Ensures derivatives must share back
- Critical infrastructure stays open forever
- Applied to: Calculation engine, historical database, core algorithms

CC BY-SA 4.0 - Content & Data

- Creative Commons Attribution-ShareAlike
- Same license Glazy uses for community data
- Applied to: Pioneer data, historical content, educational materials

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Internationalization

Ceramics is a global art. This platform will support:

Languages (Priority Order)

1. **English** - Primary development language
2. **Spanish** - Large ceramics community (CMW already offers Spanish courses)
3. **Chinese (中文)** - Ancient ceramics tradition, huge modern community
4. **Japanese (日本語)** - Strong ceramics culture, different terminology
5. **German (Deutsch)** - Historical ceramic science (Seger's language)
6. **Korean (한국어)** - Strong contemporary ceramics tradition

Technical Approach

- String externalization from day one
- Translation-ready architecture
- Regional terminology mapping tables
- Material name equivalents across traditions
- Cone system conversions (Orton, Seger, Staffordshire)

Historical Preservation & Timeline

A core pillar: preserving the history of ceramic science from 1780s to present.

Scope

- **Time range**: 1780s (Wedgwood's pyrometer) through present
- **Content**: Pioneers, publications, institutions, events, discoveries
- **Sources**: Primary documents with permanent archive links

Database Schema

```
historical_periods    - Eras (Industrial Revolution, Digital Era, etc.)

pioneers              - Biographical data, dates, contributions

publications          - Papers, books with archive links

institutions          - Lunar Society, Alfred University, etc.
```

```
timeline_events       - Dated events with significance

primary_sources       - Links to Archive.org, HathiTrust, etc.

relationships         - Linking pioneers ↔ publications ↔ events
```

Collection Methodology

- Auto-collection pattern: When researching any topic, check if historical context fits
- Rich metadata on every record (who, when, why, source)
- Provenance chains linking data to origins
- Multiple format copies (JSON + Markdown narrative)

Archive Links (Primary Sources)

- **Archive.org**: R.T. Stull publications, historical texts
- **HathiTrust**: Academic ceramic engineering publications
- **Google Books**: Transactions of American Ceramic Society
- **Software Heritage**: This project's source code preservation

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Pioneers & Credits

Honoring those who built the foundation of ceramic science.

Historical Pioneers (Pre-1900)

Name	Years	Contribution
Josiah Wedgwood	1730-1795	First pyrometric device (1782), Fellow of Royal Society, Lunar Society member
Hermann Seger	1839-1893	Unity Molecular Formula, Seger cones, systematized glaze chemistry (Germany)

Edward Orton Jr.	1863-1932	Standardized cone manufacturing, Orton cones (USA), honored Seger's legacy

Early 20th Century Research

Name	Years	Contribution
R.T. Stull	1875-1944	Stull Chart (1912), silica:alumina mapping, University of Illinois

Key Publications:

- "Influences of Variable Silica and Alumina on Porcelain Glazes" (1912) - *Transactions of the American Ceramic Society*, Vol. 14, pp. 62-70
- "Deformation Temperatures of Some Porcelain Glazes" (1913-14)

Modern Educators & Authors (1950-2000)

Name	Contribution
Daniel Rhodes	1911-1989, *Clay and Glazes for the Potter* (1957), Alfred University professor
Ian Currie	d. 2011, Grid Method for systematic glaze testing, *Revealing Glazes*
Robin Hopper	Updated Rhodes' book, contemporary ceramics

Digital Era (2000-Present)

Name / Organization	Contribution
Tony Hansen / Digitalfire	30+ years of ceramic science education, Insight software, West & Gerrow coefficients, digitalfire.com

Derek Philipau / Glazy	Open-source ceramics database, D3.js Stull visualization, glazy.org, glazy-data repository
Matt Katz / Ceramic Materials Workshop	Cone 6 Stull adaptations, modern research, educational courses, ceramicmaterialsworkshop.com
Linda Arbuckle	GlazeChem database, educational materials, calculation tutorials

Data Contributors

Name	Contribution
John Sankey	Glaze database, thermal expansion research
Alisa Clausen	Extensive glaze testing, contributed to Glazy seed data
Louis Katz	Hyperglaze database

Historical Context: The Lunar Society

Josiah Wedgwood was a founding member of the **Lunar Society of Birmingham** (1765-1813), alongside James Watt (steam engine), Matthew Boulton, and Erasmus Darwin (Charles Darwin's grandfather). This "club of industrialists" met by the full moon and helped ignite the Industrial Revolution. Wedgwood modeled his Etruria pottery factory on Boulton's Soho Manufactory.

This connection reminds us that ceramic science has always been intertwined with broader technological progress.

Scientific Calculation Engine

Professional-grade chemistry calculations with dual precision modes.

Precision Modes

Standard Mode (Default)

- 2 decimal molecular weights (industry standard)
- West & Gerrow thermal expansion coefficients (Digitalfire/Insight standard)
- Practical for everyday glaze work

Scientific Mode (Optional)

- NIST-grade molecular weights (6+ decimal precision)
- Selectable coefficient sets: West & Gerrow, Appen, Hall, Mayer & Havas
- For research, detailed analysis, or when subtle Stull chart shifts matter

Authoritative Data Sources

- **Molecular weights**: Standard chemistry reference (matches Glazy, Digitalfire)
- **Thermal expansion**: West & Gerrow as default (most consistent for comparative work)
- **Limit formulas**: Glazy, Digitalfire, CMW research
- **Material analyses**: Digitalfire database, Glazy public data

Oxide Groupings (Seger/UMF Standard)

```
R₂O  (Alkalis)        : Li₂O, Na₂O, K₂O

RO   (Alkaline Earths): CaO, MgO, ZnO, BaO, SrO

R₂O₃ (Stabilizers)    : Al₂O₃, B₂O₃*, Fe₂O₃

RO₂  (Glass Formers)  : SiO₂, TiO₂, ZrO₂

*B₂O₃ has dual role: stabilizer AND flux in low-fire glazes
```

Cone-Specific Limit Formulas

Cone Range	Al_2O_3	SiO_2	B_2O_3	Source
06-04 (Low)	0.1-0.3	1.5-3.0	0.15-0.5	Digitalfire, Glazy
5-7 (Mid)	0.28-0.64	2.4-4.7	0-0.35	Digitalfire, CMW

9-10 (High)	0.4-0.8	3.0-5.5	0-0.1	Digitalfire

Key Ratios

- **Si:Al for glossy**: 7-10:1
- **Si:Al for matte**: 5:1 or lower
- **Flux balance**: KNaO vs alkaline earth affects surface and color

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Authoritative Resources & Archives

Primary sources with permanent links for future reference.

Original Publications

- **R.T. Stull (1912)**: "Influences of Variable Silica and Alumina on Porcelain Glazes"
  - *Transactions of the American Ceramic Society*, Vol. 14, pp. 62-70
  - Google Books: https://books.google.com/books?id=9qwYAQAAIAAJ
- **R.T. Stull (1913-14)**: "Deformation Temperatures of Some Porcelain Glazes"
  - Archive.org: https://archive.org/details/deformationtempe21stul
- **Hermann Seger**: *The Collected Writings of Hermann August Seger* (1902)
  - American Ceramic Society English translation

Modern Digital Resources

- **Digitalfire**: https://digitalfire.com - Tony Hansen's ceramic encyclopedia
- **Glazy**: https://glazy.org - Open-source recipe database
- **Glazy-data repository**: https://github.com/derekphilipau/glazy-data
- **CMW**: https://ceramicmaterialsworkshop.com - Matt Katz's research

Visualization References

- **Derek Philipau's D3.js Stull Charts**: https://derekphilipau.github.io/ceramic-chemistry-visualization/charts/
  - Reference implementation for future interactive visualization

Archives

- **Archive.org**: Historical ceramic publications
- **HathiTrust**: Academic texts, University of Illinois bulletins
- **Software Heritage**: Permanent source code archival

Future Visualization

Reference for future development of interactive Stull charts.

D3.js Approach (Derek Philipau)

- Multi-layer rendering: zone backgrounds + scatter plot + color-coded data
- Recipe data loaded from external JSON
- Hover interactions showing recipe details
- Click-through to full recipe
- Color-coding by R_2O:RO flux ratio

Why D3.js for Web

- Complex layered charts not possible with simpler libraries
- Real-time updates as recipes are added/modified
- Subtle positional shifts visible during blend calculations

Matplotlib for Print

- High-DPI export for studio printouts
- Publication-quality figures
- Static analysis snapshots

Future Considerations

To be addressed in future development:

Accessibility

- Vision accessibility (screen readers, high contrast)

- Motor accessibility (large touch targets for clay-covered hands)
- Cognitive accessibility (clear, simple explanations)

Summary

This platform aims to be the most comprehensive, useful, and accessible ceramics knowledge tool ever created. It combines:

1. **Authority** - Built on DigitalFire's 7,730+ pages of expert knowledge
2. **Scale** - 20,000+ recipes for pattern discovery
3. **Preservation** - Legacy data from decades of the ceramics community
4. **Intelligence** - AI-powered discovery and explanation
5. **Practicality** - Tools potters actually need at the wheel and kiln
6. **Longevity** - Built to grow and improve over years
7. **Historical Context** - Honoring pioneers from Wedgwood to Glazy
8. **Future-Proof** - FAIR principles, archival standards, self-documenting design

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Created with care for the ceramics community. Built to last.

This project aspires to be part of ceramics history itself.