Anime Cel Pigment References
Preservation Project (v1.1)

Technical specifications for STAC / Taiyo-Shikisai /
USA-Cartoon Colour Cel-Vinyl colour charts
including sRGB / CMYK / PANTONE matching system.

Version 1.1 • August,, 2025
European ICC Profile (ECI/FOGRA)

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Cel Animation Paint Manufacturing: *Technical Processes and Industrial History*

ABSTRACT

The cel animation paint manufacturing industry represents a unique intersection of advanced chemistry, precision manufacturing, and cultural craft knowledge that enabled the golden age of hand-drawn animation.

STAC (Saito Tele-Anima colours Co. Ltd.) and Taiyo-Shikisai together dominated Japan's cel paint market for over three decades, producing the precise vinyl-acrylic formulations that defined iconic anime productions from Dragon Ball and Sailor Moon to Studio Ghibli films.

These companies didn't just mix paint—they engineered complex chemical systems requiring **vinyl acetate binders, precisely-sised pigment particles, and layer-specific colour compensation** to create the vibrant, opaque coatings that could maintain colour fidelity across thousands of individual cels while adhering to non-porous acetate surfaces.

Their manufacturing processes demanded specialised formulations that took decades to perfect, master craftsmen, and quality control systems that disappeared almost overnight when the industry digitised in the early 2000s.

The complete industry transformation from a **20 million yen monthly market to 500,000 yen** represents one of the most dramatic technological transitions in manufacturing history, illustrating both the transformative power of technological change and the fragility of specialised manufacturing knowledge. While modern efforts work to preserve and recreate traditional capabilities, the original expertise embodied by companies like STAC and Taiyo-Shikisai—representing the culmination of 50 years of incremental technical development—remains largely irreplaceable.

Their legacy lives on in the thousands of animated productions that continue to influence global popular culture, representing one of the most successful applications of specialised chemical manufacturing to artistic expression in industrial history.

The chemistry behind cel animation pigments

Cel animation paints demanded radically different chemistry than conventional coatings.

The unique challenge of **achieving single-coat opacity on non-porous acetate surfaces** while maintaining perfect colour consistency across thousands of individual cels required specialised formulations that took decades to perfect.

Pigment systems combined both organic and inorganic compounds optimised for specific performance requirements. *Titanium dioxide* provided the opacity foundation, comprising 15-25% by weight in opaque formulations, while *iron oxides* supplied earth tones and *quinacridone* pigments delivered the vibrant reds and magentas that characterised animation palettes.

The critical factor wasn't just colour—**particle size had to remain between 30-40 micrometers** to achieve proper light scattering without compromising film formation.

The binder chemistry represented the most technically sophisticated aspect of cel paint manufacturing.

Polyvinyl acetate (PVAc) systems with glass transition temperatures of 30-45°C provided the hard, fast-drying characteristics essential for production workflows. However, pure vinyl systems required *plasticisers* and *copolymers*—particularly *vinyl acetate-ethylene* combinations—to achieve the flexibility and adhesion properties necessary for acetate substrates.

Manufacturing processes relied on **three-roller milling systems requiring 3-5 passes** to achieve proper pigment dispersion.
Target fineness measured 4-7 Hegman units, with grinding parameters carefully controlled to prevent temperature rises that could damage heat-sensitive organic pigments.
Quality control systems monitored viscosity (70-90 Krebs Units), pH levels (8-10 for water-based systems), and colour consistency using spectrophotometric analysis measuring CIE L*a*b* colour space differences between batches.

STAC: Toei Animation's exclusive paint supplier

STAC's founding in **1969 by Kitamura Shigeharu** positioned the company at the epicenter of Japan's television anime boom. The former *Kyurinkan In*k employee recognised that colour television animation demanded specialised paint formulations far beyond existing industrial coatings.

The company's **exclusive relationship with Toei Animation** created a unique business model based on custom manufacturing rather than mass production. STAC produced approximately **250 different colours**, each formulated specifically for Toei's production requirements and colour palette standards.

This arrangement enabled productions like Dragon Ball, Saint Seiya, and Sailor Moon to maintain the vibrant, consistent colour schemes that became synonymous with high-quality Japanese animation.

Manufacturing operations required expert craftsmen whose skills encompassed colour matching, consistency control, and understanding of how paint formulations would appear under different lighting conditions during filming. Each colour batch demanded individual attention, with skilled workers adjusting formulations based on temperature and humidity variations that could affect final colour appearance.

The technical specifications STAC developed became **industry standards adopted throughout Japanese animation production**. Their proprietary colour numbering system, quality control protocols, and formulation techniques influenced animation paint manufacturing globally. Studios maintained approximately **400 colours in active inventory**, with STAC's formulations calibrated to compensate for transparency effects when multiple cel layers were photographed together.

STAC's inability to adapt to the digital transition proved fatal to the company. **Unlike competitors who diversified or found alternative markets**, STAC's exclusive focus on cel paint manufacturing left them without viable business options when demand disappeared in the early 2000s.

The company ceased operations as digital ink and paint systems eliminated the need for physical paint production.

Taiyo-Shikisai, the industry duopoly

The **1975 founding of Taiyo-Shikisai by the same Kitamura Shigeharu** created the duopoly that would dominate Japanese cel paint manufacturing for the next 25 years. This strategic move positioned Kitamura to supply virtually all major animation studios—STAC serving Toei Animation while Taiyo-Shikisai captured contracts with most other producers.

Taiyo-Shikisai's market position demonstrated the economics of specialised manufacturing at its peak. **Monthly revenues of 20 million yen ($200,000)** during the height of cel animation production provided substantial profits from what was essentially a craft manufacturing operation.

The company's success reflected both the technical sophistication required for consistent paint production and the critical importance of colour quality in animation production.

The dramatic revenue collapse to **500,000 yen ($5,000) monthly by 2007** illustrates the complete market transformation following digital conversion. Company head Shigeji Kitamura's commitment to continuing production despite financial losses:

"*It's the culture of Japan. We want to continue making the paints even if that cuts into our profits*"—reflects the cultural significance of traditional animation techniques beyond mere commercial considerations.

Taiyo-Shikisai's formulations incorporated STAC's original colour system while expanding the available palette to meet diverse studio requirements. The company's broader market approach enabled them to develop relationships with multiple studios and understand varied production requirements across different animation styles and budgets.

Global cel paint manufacturing ecosystem

The international cel paint manufacturing industry encompassed several specialised companies serving regional animation markets with distinct technical approaches and business models.

Cartoon Colour Company, founded in 1947 in Culver City, California, established the American standard for cel-vinyl paint manufacturing. The company supplied major studios including Disney, Warner Bros, and MGM with **over 2,000 different colours** during peak production periods. Their formulations enabled the distinctive visual style of American animation from the post-war era through the 1990s digital transition.

Chromacolour in the United Kingdom developed formulations "*based on same original formula used for Who Framed Roger Rabbit*," producing **extremely pigment-rich formulations with matt, flat finish** that became the European standard. Their manufacturing approach emphasised single-coat coverage and consistency across large production runs required for feature film production.

NICKER COLOUR CO., LTD. represents the high-end segment of animation paint manufacturing, utilising **highest quality Gum Arabic from Sudan** rather than standard dextrin-based binders.

Founded in 1950, the company employed traditional craftsmen with **40+ years experience using three-roller milling machines** to produce poster colours and gouache primarily for animation backgrounds. Their formulations became standard at Studio Ghibli and other quality-focused production houses.

The technical evolution across manufacturers reflected different approaches to the same fundamental challenges. American manufacturers emphasised consistency and volume production for series animation, while Japanese companies focused on colour sophistication and custom formulations for diverse visual styles. European manufacturers balanced both approaches while developing specialised formulations for international co-productions.

Manufacturing technology and quality control systems

The technical sophistication of cel paint manufacturing encompassed precision chemistry, specialised equipment, and quality control systems that rivaled pharmaceutical production in their attention to consistency and purity.

Three-roller milling technology formed the heart of pigment dispersion processes, with each pass through the rollers achieving progressively finer particle sizes and more uniform distribution. The mechanical forces involved—typically 1000-3000 RPM for 15-30 minutes during initial dispersion—required careful temperature control to prevent thermal degradation of organic pigments and polymer binders.

Quality control systems measured multiple parameters simultaneously to ensure batch consistency. **Stormer viscometers provided standard industry measurements**, while Hegman gauges assessed fineness of grind and particle size distribution. Spectrophotometric analysis using CIE L*a*b* colour space measurements enabled precise colour matching between batches, with acceptable deviation limits typically less than ΔE=1.0 for critical colours.

Raw material control systems included incoming inspection protocols, certificate of analysis verification, and lot-to-lot variation monitoring for all pigments and resins. Automated dispensing systems ensured consistent formulations across production runs, while statistical process control implementation enabled real-time adjustments based on sensor feedback.

The manufacturing environment required precise humidity and temperature control, with **minimum film formation temperatures typically 5-15°C** and optimal production conditions maintained within narrow ranges. Paint storage and handling systems prevented contamination while maintaining proper flow characteristics throughout the production process.

Industrial transformation and cultural preservation

The complete transition from cel to digital animation between 1990-2013 represents one of the most rapid and thorough technological transformations in manufacturing history, eliminating an entire specialised industry within a single generation.

Japan's transition timeline demonstrates the speed of change: major studios began digital conversion in 1999 (Chibi Maruko-chan), accelerated through 2002-2003, and concluded with Sazae-san's conversion in October 2013.

This represented the end of **over four decades of continuous cel paint production** and the elimination of specialised manufacturing knowledge developed over generations.

The cultural significance of this transformation extends beyond industrial economics to encompass the preservation of craft knowledge and technical expertise.

Modern revival efforts like CEL LAB work to recreate traditional cel painting capabilities through collaboration with paint manufacturers, while institutions like the Media Arts Current Contents (MACC) document traditional techniques for cultural preservation.

Environmental and safety considerations also drove industry changes. The transition from dangerous **celluloid (which posed spontaneous combustion risks) to tri-acetate cellulose (TAC)** improved workplace safety, while updated Industrial Safety and Health Act requirements demanded comprehensive risk assessments for chemical substance handling.

The complete end of domestic acetate film production over 100μ thickness by 2021 marked the final closure of traditional animation material manufacturing in Japan.

Contemporary companies like NICKER continue serving niche markets with traditional formulations, while alternatives like **Holbein Acryla Gouache** provide closest substitutes for traditional cel-vinyl properties.

However, the specialised manufacturing expertise, colour consistency systems, and craft knowledge that enabled companies like STAC and Taiyo-Shikisai to produce thousands of precise colours for animation production largely disappeared with the digital transition.

Farewell, cel animation

To conclude, I want to quote an editorial column by **Yuichiro Oguro (小黒祐一郎)**, published in the WEB publication Anime Style Magazine:

September 30, 2013

“Farewell, Cel Animation“

Even after almost the entire anime industry transitioned to digital production, only Sazae-san continued to be produced using cel animation and film.

That Sazae-san too—yesterday's broadcast was apparently the last episode produced using cel animation and film. From the next episode onward, it will transition to digital production. In other words, yesterday marked the end of cel animation in Japan.

I myself have grown accustomed to watching digitally produced anime and enjoy its crisp imagery, so I won't say something like "the analogic era was better" at this point.

There are opinions that "anime had more warmth in its visuals during the cel animation era." I don't completely deny this, but perhaps half of that warmth might be wishful thinking on the viewers' part. Even with Sazae-san, special programs had been digitised quite some time ago, and recently there were digitally produced episodes mixed into regular broadcasts. When digitally produced episodes aired, surely not many viewers were bothered by changes in colour or texture, and even with the complete transition to digital production, people will probably get used to it quickly.

Still, I feel a touch of melancholy about the disappearance of cel animation.

That's only natural, since it's something I've been familiar with since childhood.

Since the transition to HD production, Sazae-san had become noticeably affected by cel dust. When watching on a large TV, you could see the dust.

Every time I saw this, I would think "Ah, they're still shooting cel animation" and feel relieved. I don't really understand what I was feeling relieved about. But that "sense of relief" will now disappear.

Farewell, cel animation.

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Technical Colour Workflow for almost any classic Anime / Cel Pigment Charts

SUMMARY

This document consolidates sources, specifications, decisions, and reference code to generate sRGB, CMYK samples and identify closest Pantone tones from CIE L*a*b* values for:

* スタック（*STAC：Saito Tele-Anima Colors Co. Ltd.*）
* 太陽色彩（*TAIYO-SHIKISAI/ 太陽色彩株式会社 ANIMATION. PAINT*）
* **Cartoon Cel-Vinyl** Colour Charts

INDEX

Version: 1.1 • Date: 24/08/2025 • Scope: Europe (ICC ECI/FOGRA commercial printing profiles)

1. Sources (LAB, RGB, Hex sRGB, Hex ProPhoto, HSL)

The Colour specifications originate from captures and measurements performed on pigment charts for cels (vinyl).

The original dataset (with no Pantone nor CMYK conversions) was sourced from the Kanzenshuu community forum:

```
Excel Colour List Source: https://www.kanzenshuu.com/forum/viewtopic.php?t=19448
```

I am grateful for the work carried out, which has made it possible to perform the rest of the conversions and cataloguing presented in this document

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Original Measuring Devices specs (From Analogic to Digital data) :

Measuring Device	Date Created	Notes
Epson Perfection v600	2021-12-27	48-bit scanning, ProPhoto RGB embedded ICC profile
ColourMunki Photo	2024-05-23	Spectrophotometric remeasurement D50/2° standard observer
X-Rite i1Pro 2	2025-04-09	Final wide-gamut capture addressing metamerism issues

Technical scanning and conversion specifications notes :

• Many pigment Colours exceed sRGB gamut boundaries. Accurate display requires Rec.2020 compatible monitors (limited availability as of 2021).

• Original charts scanned at 48-bit depth, saved as TIFF with embedded ProPhoto RGB ICC profile for maximum Colour fidelity.

• Spectrophotometric remeasurement provided device-independent CIE L*a*b* values as ground truth references.

• Derived sRGB values computed from L*a*b* coordinates with gamut clipping applied when Colours fall outside sRGB boundaries.

• Neutral reference points standardized:Closest Pantone calculation from L*a*b* (∆E00)

BLACK at LAB(6,0,0)   sRGB(19,19,19), WHITE at LAB(95,0,0)   sRGB(240,240,240)

• STAC <-> Taiyo-Shikisai **conversions implemented via Toei Animation in-house lookup table** (not physically equivalent Colours).

• Physical chart aging and yellowing affected low-saturation/high-lightness samples. Retrobright treatment applied to restore accuracy.

Database evolution timeline :

Date	Update Description
2025-08-24	**Consolidation for STAC / TAIYO / USA CARTOON colour charts by including real CMYK values (using a PSOcoated V3 ICC colour profile).** **All the colour charts catalogued in one document (this one!) as faithfully as possible to the original values, both in print (CMYK) and digitally on screen (sRGB).**
From here backwards, it corresponds to the original Excel work provided in the forum	
2022-05-18	Integration of older STAC chart scan Colour code nomenclature updates Deprecated codes mapping established
2022-07-25	ProPhoto RGB hexadecimal values added for workflow convenience
2023-01-19	Complete X-Colour chart digitization

2023-01-20	STAC A-Colour (those created by TOEI for USA animes) chart integration
2023-01-27	sRGB HSL values computed and added for UI/web design applications
2023-02-21	STAC Taiyo-Shikisai conversion table implemented from Toei reference
2023-04-30	Taiyo-Shikisai 595-Colour edition 8-booklet comprehensive scan
2024-01-15	Extended STAC Taiyo-Shikisai mapping with additional missing entries
2024-05-13	STAC spectrophotometric recapture replacing scanner-based measurements
2024-05-15	Sun Colour spectrophotometric update scanner version retained as reference
2024-05-29	X-Colour and A-Colour post-retrobright recapture with enhanced accuracy
2025-02-01	Cel-Vinyl chart addition wide-gamut colours beyond instrument limits
2025-04-09	Comprehensive i1Pro2 recapture metamerism correction for violet/pink hues

2) ICC profiles and European selection (ECI/FOGRA)

For European commercial offset printing on coated substrates, the workflow employs **PSO Coated v3** (European Colour Initiative) as the primary CMYK destination profile.

This profile represents current industry standards for high-quality commercial printing and supersedes historical FOGRA39 in contemporary workflows.

Screen display maintains sRGB IEC61966-2-1 ICC profile compliance for maximum device compatibility and consistent Colour reproduction across standard monitors.

Technical profile specifications :

• **CMYK Output Profile:** PSO Coated v3 (ECI) - European commercial coated paper standard

• **Colour Reference Space:** CIE L*a*b* D50/2° standard observer (device-independent ground truth)

• **RGB Working Space:** sRGB IEC61966-2-1 for display, ProPhoto RGB for archival/editing

• **Gamut Management:** Out-of-gamut Colours handled via ICC profile rendering intent (perceptual/relative Colourimetric)

• **Alternative Substrates:** FOGRA52 (uncoated), PSO Uncoated v3 (uncoated), FOGRA51 (newsprint)

Through the original script, using the Pantone-to-Lab CSV, it is possible to choose the ICC profile in use.

NOTE: This will positively affect the final colour displayed in CMYK; as an advantage, it allows adapting the document to any printing house in the world that may require any other type of ICC.

3) Colour Processing: Technical Decisions

The colour space conversion implements a two-stage transformation pipeline to ensure compatibility with standard imaging libraries:

(i) CIE L*a*b*   sRGB intermediate conversion, followed by (ii) sRGB CMYK conversion using **PSO Coated v3.icc** profile.

Data Preservation Strategy :

```
# Original data always preserved
original_data = {
    'L': 25.4,    # 1 decimal precision
    'a': -1.5,    # 1 decimal precision
    'b': -5.0,    # 1 decimal precision
    'R': 55, 'G': 61, 'B': 68  # Integer values
}

# Computed data maintains separate namespace
computed_data = {
    'C': 9.41,    # 2 decimal precision
    'M': 5.88,    # 2 decimal precision
    'Y': 14.12,   # 2 decimal precision
    'K': 0.00     # 2 decimal precision
}
```

Colorimetric Conversion Chain :

```
def lab_to_cmyk(self, L, a, b):

    """
    Convert LAB to CMYK using ICC profile transformation

    Critical decisions:
    1. Relative Colorimetric rendering intent
    2. Black Point Compensation enabled
    3. PSOcoated_v3.icc for print accuracy
    """

    # Validate and clamp input values
    L_val = max(0, min(100, float(L)))
    a_val = max(-128, min(127, float(a)))
    b_val = max(-128, min(127, float(b)))

    # PIL LAB format conversion
    lab_image = Image.new("LAB", (1, 1))
    lab_image.putpixel((0, 0), (

        int(L_val * 2.55),      # L* 0-100 → 0-255
        int(a_val + 128),       # a* -128..127 → 0-255
        int(b_val + 128)        # b* -128..127 → 0-255

    ))

    # Transform using ICC profile
    cmyk_image = ImageCms.applyTransform(lab_image, self.transform)
    c, m, y, k = cmyk_image.getpixel((0, 0))

    return (c/255.0)*100, (m/255.0)*100, (y/255.0)*100, (k/255.0)*100
```

Presicion Requeriments - Decimal precision standards

Data Type	Precision	Rationale
LAB Values	1 decimal	Industry standard, adequate for visual discrimination
XYZ Tri-stimulus	1 decimal	Matches spectrophotometer output precision
RGB Values	Integer	8-bit color depth standard
CMYK Percentages	2 decimals	Print industry requirement for dot gain calculations
Delta E CIE2000	3 decimals	Critical for <1.0 imperceptible threshold detection
Hex Values	Standard	#RRGGBB format, uppercase

Presicion Requeriments - Delta E Thresholds

```
DELTA_E_THRESHOLDS = {

    'imperceptible': 1.0,      # JND (Just Noticeable Difference)
    'barely_perceptible': 3.0, # Trained observer threshold
    'perceptible': 6.0,        # Average observer threshold
    'clearly_visible': 10.0    # Obvious color difference

}
```

Delta E CIE-2000 Implementation

The colour space conversion implements a two-stage transformation pipeline to ensure compatibility with standard imaging libraries:

```
def calculate_delta_e_cie2000(self, lab1, lab2):
    """
    CIE2000 Delta E calculation with complete implementation

    Key improvements over CIE76/CIE94:
    - Accounts for blue region distortions
    - Improved neutral color handling
    - Perceptually uniform chroma scaling
    """
    L1, a1, b1 = lab1
    L2, a2, b2 = lab2

    # Weighting factors (industry standard)
    kL = kC = kH = 1.0

    # Chroma calculation with G factor correction
    C1 = math.sqrt(a1**2 + b1**2)
    C2 = math.sqrt(a2**2 + b2**2)
    C_avg = (C1 + C2) / 2.0

    # G factor for improved chroma scaling
    G = 0.5 * (1 - math.sqrt(C_avg**7 / (C_avg**7 + 25**7)))

    # Prime values with G correction
    a1_prime = a1 * (1 + G)
    a2_prime = a2 * (1 + G)

    # Continue with CIE2000 algorithm...
    # [Full implementation in color_processor.py]
```

Quality Assesment Framework

```
def categorize_delta_e(self, delta_e):

    """Categorize conversion quality based on Delta E"""
    if delta_e < 1.0:

        return 'excellent'      # Imperceptible difference
    elif delta_e < 3.0:

        return 'good'           # Barely perceptible
    elif delta_e < 6.0:
        return 'acceptable'     # Noticeable but usable

    elif delta_e < 10.0:

        return 'problematic'    # Clearly visible

    else:
        return 'unacceptable'   # Significant color shift
```

4) Closest Pantone calculation from L*a*b* (ΔE00)

Pantone Colour matching employs CIE ΔE00 (CIEDE2000) Colour difference formula to quantify perceptual Colour differences between target CIE *L*a*b** coordinates and Pantone Solid Coated (C) reference library.

The algorithm identifies the Pantone Colour with minimum ΔE00 value, providing the closest perceptual match.

CIEDE2000 (ΔE00) represents the most advanced Colour difference formula, incorporating corrections for lightness, chroma, and hue perception non-linearities, particularly in blue and gray regions where human visual system exhibits reduced discrimination sensitivity.

Euclidean Distance in Perceptual Space :

```
def find_closest_pantone(self, L, a, b, max_delta_e=None):
    """
    Pantone matching using CIE2000 in LAB space

    Decision rationale:
    - LAB space provides perceptual uniformity
    - CIE2000 handles edge cases better than CIE76
    - Database of 2000+ Pantone colors with LAB values
    """

    input_lab = (float(L), float(a), float(b))
    best_match = None
    min_delta = float('inf')

    for pantone in self.pantone_database:
        pantone_lab = (pantone['L'], pantone['a'], pantone['b'])
        delta_e = self.calculate_delta_e_cie2000(input_lab, pantone_lab)

        if delta_e < min_delta:
            min_delta = delta_e
            best_match = pantone

    return best_match['name'], best_match['code'], min_delta
```

ΔE00 interpretation and technical considerations :

- **ΔE00 < 1.0:** Imperceptible difference under standard viewing conditions
- **ΔE00 1.0-2.0:** Barely perceptible to trained observers under optimal conditions
- **ΔE00 2.0-5.0:** Noticeable difference but acceptable for commercial applications
- **ΔE00 5.0-10.0:** Clear Colour difference, requires attention in critical applications
- **ΔE00 > 10.0:** Distinctly different Colours, unsuitable for Colour matching

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Technical limitations and accuracy considerations :

- **Some colours** exceed Pantone Solid Coated gamut boundaries, resulting in E00 > 5.0
- Colour matches valid under D50 illuminant may vary under different light sources
- Pantone physical standards have ±1.5 ΔE00 manufacturing tolerance
- **Spectral Considerations** → Fluorescent or metallic pigments cannot be accurately matched to conventional Pantone Colours
- Individual Colour perception differences may affect practical Colour matching results

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**Calculations performed here maintain values below ΔE00 3.0,
making the conversions as faithful as possible in the most cases.**

5) Conversion Quality Metrics

For professional Colour documentation r**equiring both screen display and print reproduction**, the recommended format presents dual Colour swatches (sRGB and real CMYK simulation) accompanied by comprehensive technical data tables, by ensuring accurate colour communication across digital and print media workflows.

Future EPUB implementation should embed RGB Colour swatches with sRGB ICC profile metadata while maintaining numeric Colour data in accessible text format.

PDF/X standards are reserved for pre-press applications requiring embedded CMYK Colour spaces.

```
class QualityMetrics:
    def __init__(self, conversion_results):
        self.cmyk_deltas = [r['cmyk_delta_e00'] for r in conversion_results]
        self.pantone_deltas = [r['pantone_delta_e00'] for r in conversion_results
                              if r['pantone_delta_e00'] is not None]

    def calculate_statistics(self):
        return {
            'cmyk_mean_delta': statistics.mean(self.cmyk_deltas),
            'cmyk_median_delta': statistics.median(self.cmyk_deltas),
            'pantone_mean_delta': statistics.mean(self.pantone_deltas),
            'excellent_rate': self.count_by_quality('excellent') / len(self.cmyk_deltas),
            'problematic_rate': self.count_by_quality('problematic') / len(self.cmyk_deltas)
        }
```

EXPECTD QUALITY BENCHMARKS :

Metric	Target	Rationale
CMYK Mean ΔE	< 3.0	Acceptable for print production
Excellent Rate	> 60%	Majority of colors imperceptible difference
Problematic Rate	< 10%	Minimize clearly visible color shifts
Pantone Match Rate	> 80%	Industry database completeness

ICC PROFILE INTEGRATION :

Profile Selection Rationale

```
ICC_PROFILE_DECISIONS = {
    'primary': 'PSOcoated_v3.icc',
    'reason': 'ISO 12647-2 standard for offset printing',
    'characteristics': {
        'gamut': 'Optimized for coated paper printing',
        'black_generation': 'GCR (Gray Component Replacement)',
        'rendering_intent': 'Relative Colorimetric',
        'black_point_compensation': True
    }
}
```

RENDERING INTENT ANALYSIS :

```
RENDERING_INTENTS = {
    'perceptual': {
        'use_case': 'Photographic images',
        'gamut_mapping': 'Compresses entire gamut proportionally',
        'decision': 'Not chosen - too much color shift for spot colors'
    },
    'relative_colorimetric': {
        'use_case': 'Spot colors and logos',
        'gamut_mapping': 'Clips out-of-gamut colors to nearest equivalent',
        'decision': 'CHOSEN - Preserves in-gamut colors exactly',
        'black_point': 'Compensated to avoid gray shifts'
    }
}
```

RENDERING INTENT ANALYSIS - BATCH PROCESSING STRATEGY :

```
class BatchProcessor:

    def __init__(self, chunk_size=100):
        self.chunk_size = chunk_size

    def process_colors_batch(self, color_data):
        """
        Process colors in chunks to optimize memory usage
        and provide progress feedback
        """

        total_colors = len(color_data)
        processed = 0

        for chunk_start in range(0, total_colors, self.chunk_size):

            chunk_end = min(chunk_start + self.chunk_size, total_colors)
            chunk = list(color_data.items())[chunk_start:chunk_end]



            # Process chunk with single ICC transform initialization

            for color_id, data in chunk:


                self.process_single_color(color_id, data)
                processed += 1

                if processed % 50 == 0:

                    progress = (processed / total_colors) * 100
                    print(f"Progress: {progress:.1f}% ({processed}/{total_colors})")
```

VALIDATION AND TESTINGS :

```
def validate_conversion_quality(self, results):
    """
    Automated validation of conversion results

    Fails pipeline if quality thresholds not met
    """

    quality_checks = {
        'cmyk_extreme_delta': len([r for r in results if r['cmyk_delta_e00'] > 15]),
        'missing_pantone_rate': len([r for r in results if r['pantone_name'] == 'N/A']) /
len(results),
        'invalid_rgb_count': len([r for r in results if not r['has_valid_rgb']]),
        'color_space_violations': self.check_color_space_violations(results)
    }

    # Quality gates
    assert quality_checks['cmyk_extreme_delta'] < len(results) * 0.05, "Too many extreme CMYK
deltas"
    assert quality_checks['missing_pantone_rate'] < 0.3, "Pantone match rate too low"

    return quality_checks
```

6. Considerations

1. Wide Gamut Support

- Rec2020 color space integration for future displays
- Extended gamut Pantone colors

2. Machine Learning Enhancement

- Trained models for better Pantone matching
- Metameric color prediction

3. Real-time Processing

- GPU acceleration for ICC transformations
- Streaming pipeline for large datasets

Quality assurance and validation requirements :

• Verify sRGB display under D65 illuminant, validate CMYK proofs under D50 viewing conditions

• Document out-of-gamut Colours with appropriate warning indicators and clipping notes

• Test Colour reproduction across different operating systems and display technologies

• Include textual Colour descriptions and numeric values for vision-impaired users

Warnings and technical limitations :

• Colours exceeding sRGB/CMYK gamut boundaries undergo automatic clipping with potential Colour shift

• Results are computational approximations; physical verification with Pantone Colour Bridge required

• Colour appearance depends on illuminant and observer; maintain D50/2° reference standards

• Commercial printing introduces ±2-3 E00 variation; specify acceptable tolerance ranges

7. References - Standards

- https://www.kanzenshuu.com/forum/viewtopic.php?t=19448
- http://www.style.fm/as/05_column/tsujita/tsujita_bn.shtml
- https://animestyle.jp/column/
- https://www.nekomataya.info/

- **CIE Publication 15:2004** - Colorimetry, 3rd Edition
- **ISO 12647-2:2013** - Process control for offset lithographic processes
- **CIE Technical Report 224:2017** - Colour fidelity index for accurate scientific use
- **ICC.1:2010** - Image technology colour management — Architecture, profile format and data structure

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Work done out of love for colour and preservation of hand-made anime material and techniques !

— End of Technical Documentation —

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