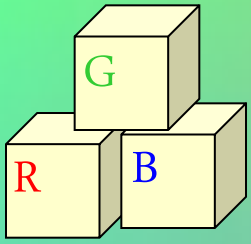


Capabilities and Limitations of Color Measurement with an RGB Camera

John Seymour
Principal Engineer – Research
QuadTech
CMM 2009

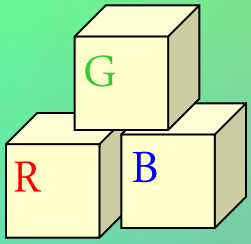




Summary

Web inspection systems
(with RGB cameras)
offer CIELAB measurements.

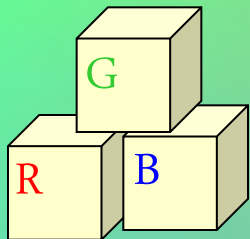
They are not very
accurate.



Summary

There is a distinction between
measuring CIELAB
and measuring ΔE

RGB cameras *can*
measure ΔE
“accurately enough”

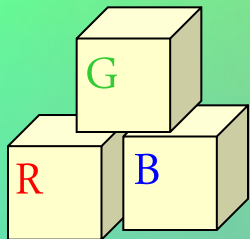


Ok, so what's a CIELAB?

- CIELAB (or $L^*a^*b^*$) measures color
- CIELAB sees color the way people do

Well... kinda

- A measurement of color is three numbers
- The numbers uniquely define the color
- If $L^*a^*b^*$ values are the same,
the colors match

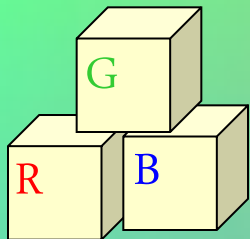


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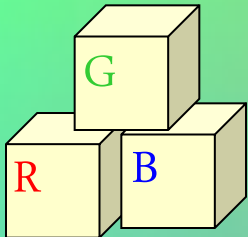


Ok, so what's a CIELAB?

Now that we have CIELAB

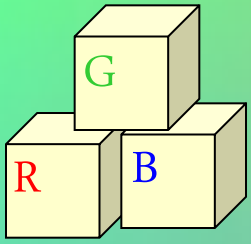
*Matching by the eye is
a thing of the past!!*

Did I mention that I am in research?



What's a ΔE ?

- A ΔE (pronounced delta-E) is a measure of color difference
 - Useful for setting tolerances
 - 1 ΔE is pretty small
 - 10 ΔE is moderate
 - 100 ΔE is way big
- 100 ΔE is the difference between black and white

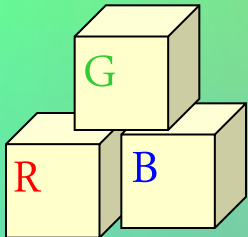


What's a ΔE ?

Ideally

1 ΔE *should have been*
a “just noticeable difference”
in color.

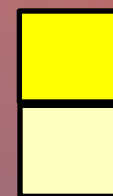
But...



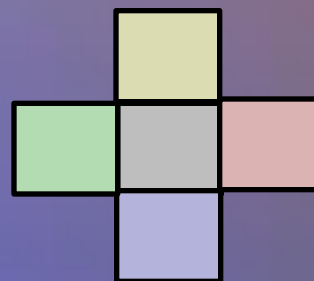
What's a ΔE ?

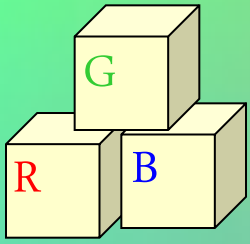
But...

5 ΔE difference in the saturation of yellow is just noticeable.



0.5 ΔE difference around gray is just noticeable.





What's a ΔE ?

So they revised the formula:

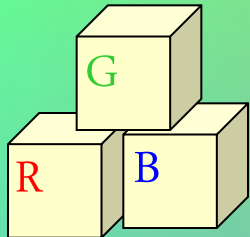
The original: ΔE , or ΔE_{76} , or ΔE_{ab}

First revision: ΔE_{CMC} (1984)

Second revision: ΔE_{94}

Third revision: ΔE_{00}

Fourth revision: ΔE_{99} , or DIN 99 ΔE



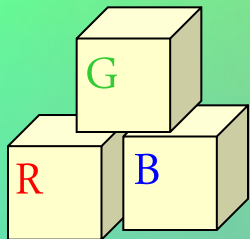
*The wonderful thing
about standards is that
there are
so many to choose from!*

We will use the original ΔE .

from the Summary...

CIELAB from an RGB camera
is not accurate enough

ΔE from an RGB camera
is accurate enough

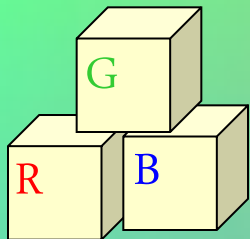


What is “accurate enough”?

First thought

the human visual system can discern down to 1 ΔE (kind of)

so a color measurement system has to do the same

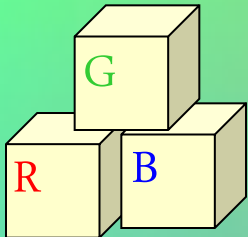


What is “accurate enough”?

Second thought

press variation is larger than $1 \Delta E$

how close do we need to hold
color anyway?



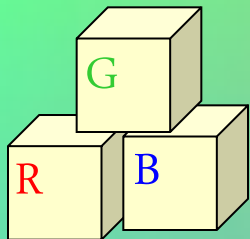
The ISO standard

ISO 12647-6:2006(E)

Graphic technology –

*Process control for the production of
half-tone colour separations, proof
and production prints –*

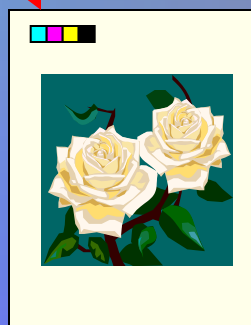
*Part 6: Flexographic printing,
Section 4.3.2.3*



12647-6 requirements

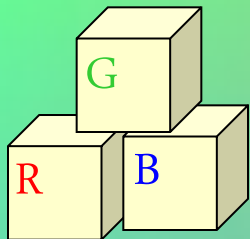
	L*	a*	b*
C	55	-36	-44
M	46	70	-3
Y	84	-5	88
K	20	0	0

Patches on the proof
must match the
numbers



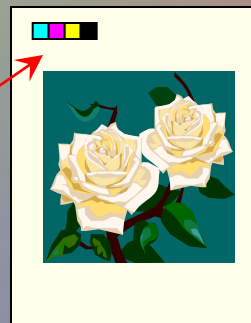
Proof

*This is not a concern
for an online
measurement device*

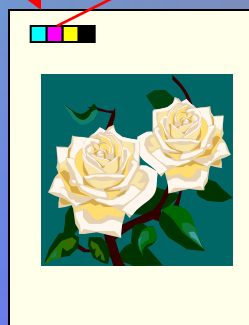


12647-6 requirements

	L*	a*	b*
C	55	-36	-44
M	46	70	-3
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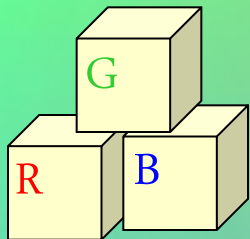


OK sheet



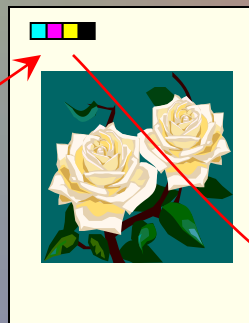
Proof

Patches on the OK sheet
must match the proof
to within $8 \Delta E$



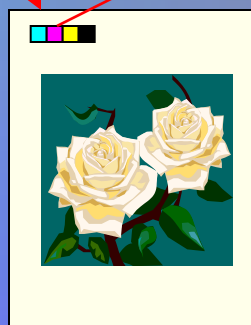
12647-6 requirements

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OK sheet

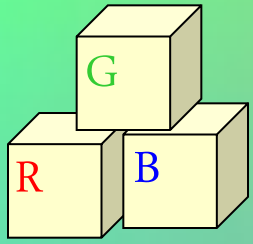
68% of patches
in production
must match the OK
sheet to within $2.5 \Delta E$



Proof



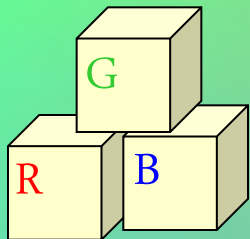
Production



What is “accurate enough”?

Accuracy tolerances of $8 \Delta E$
in measuring color ok sheet

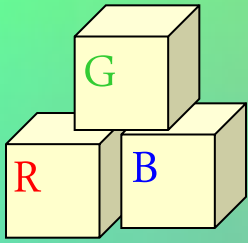
The SPC folks say we need
accuracy of at the very least
 $2.4 \Delta E$ and preferably $0.8 \Delta E$



What is “accurate enough”?

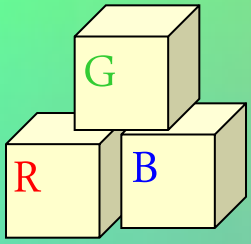
Accuracy tolerances of $2.5 \Delta E$
in measuring production sheets

The SPC folks say we need
accuracy of at the very least
 $0.75 \Delta E$ and preferably $0.25 \Delta E$



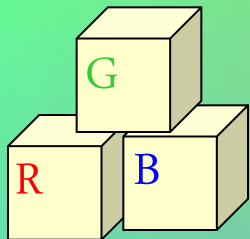
Vendor claims

- “Colour monitoring with deviations calculated and **expressed in delta E (@E) value.**”
- “**Based on the CIE-Lab colour**”
- “on-line **accurate** L*a*b* color measurement & management”
- “**accurate** in-line color measurement”
- “Today, online color monitoring accuracy has reached levels **previously attainable only with** the use of handheld **spectrophotometers.**”
- “...independent tests were undertaken to study the correlation of color results between [the web inspection system] and a spectrodensitometer. The results... found **almost a perfect correlation...**”
- “Accuracy: CIE Lab colour value: **1 ΔE**”
- “Today’s online technology allows color deviation to be measured as accurately as **0.2 Δe.**”



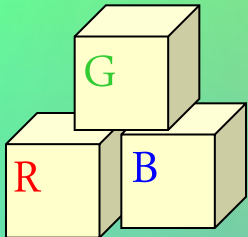
That's what marketing has to say

What does the scientific literature say?



Review of literature

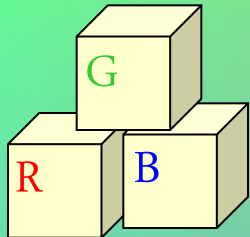
Author(s)	Data	Method	Accuracy
Kang & Anderson	236 patches (QC60)	3X6 Matrix	8 - 12
Viggiano & Wang	236 patches (QC60)	Principal Component Analysis (PCA)	4.1
Wandell & Farrell	214 CMYK	3X3 Matrix	6.0
“	“	3X3 Matrix + correction	2.4
Sodergard et al.	236 patches Newsprint	13 term polynomial	5.8
Seymour (1997)	995 CMYK	3X9 Matrix	2.0
“	24 Pantone	“	7.0
Seymour (2009)	11,664 CMYK	3X9 Matrix	1.5 – 2.4
Brydges, et al.	24 Newsprint	3X9 Matrix & PCA	1.2 -1.4
Ben Chouikha et al.	93 NCS set	3X3 Matrix	11.6
“	“	3X3 Matrix + 3rd order CIELAB regression	2.4
“	CRISATEL acrylic chart	3X3 Matrix + 3rd order CIELAB regression	5.3
Urban, et al.	1269 Munsell + Vrhel database	Metamer analysis	4.1 - 8.2



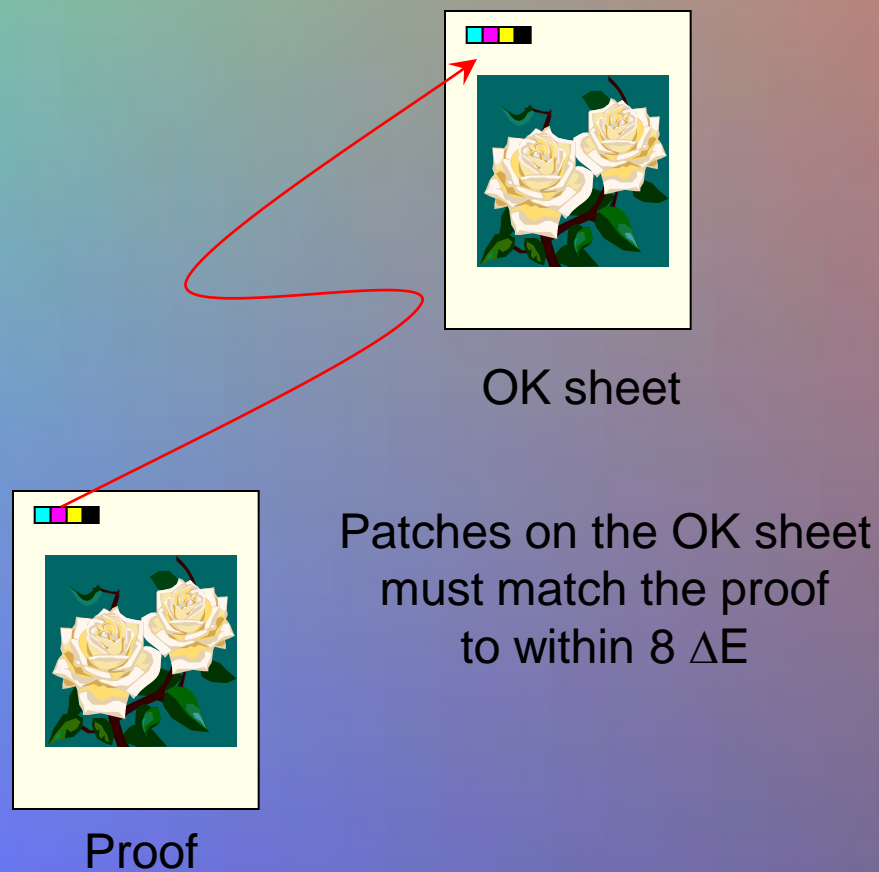
Review of literature

The most optimistic results
are just barely good enough for color ok...

and no where near good enough
for the production run.



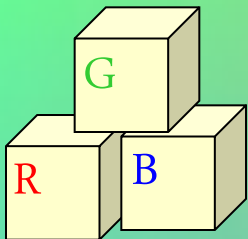
12647-6 requirements



**Different
measurement
devices**



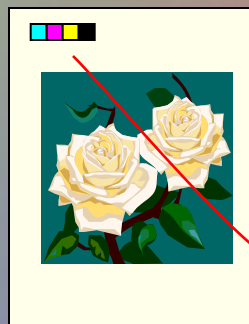
**We need
CIELAB
accuracy**



12647-6 requirements

OK and Production sheets will have wrong CIELAB values

Same camera and stock



OK sheet

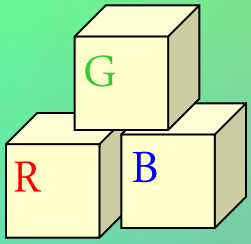
68% of patches in production must match the OK sheet to within $2.5 \Delta E$

Hopefully the errors will be similar



Production

Here we need ΔE accuracy



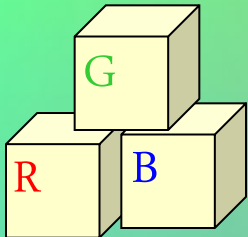
12647-6 requirements

For color ok

CIELAB values must be accurate

For production

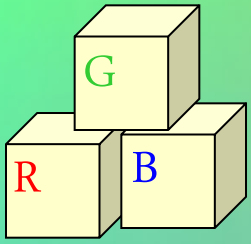
ΔE values must be accurate



Accuracy of ΔE

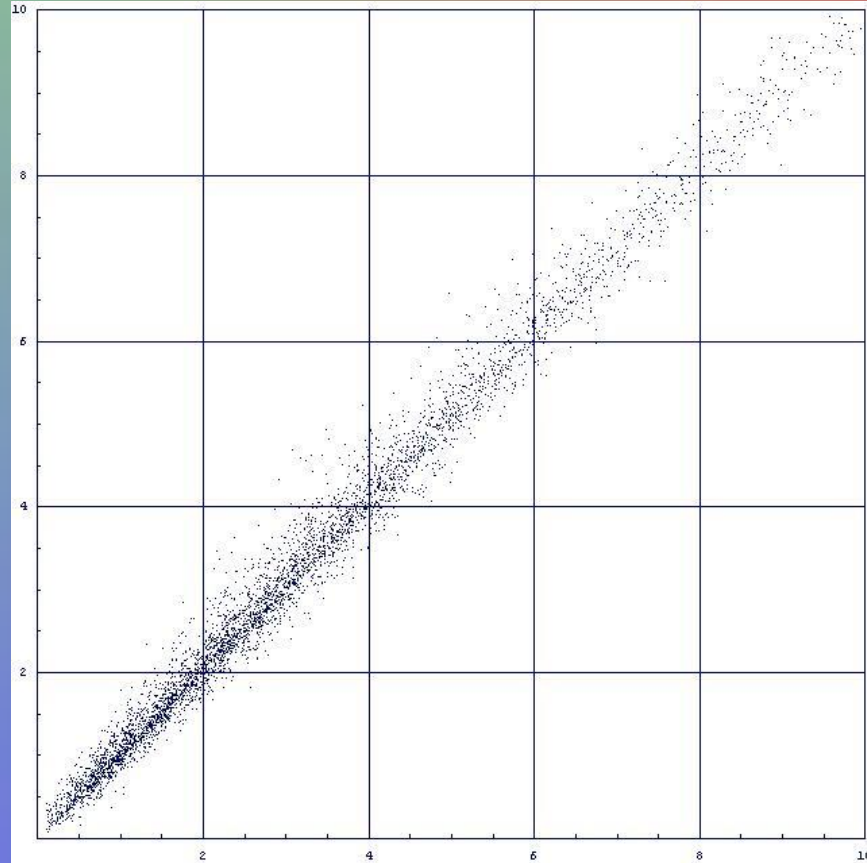
Summary of results from
my TAGA 2009 paper

on CMYK colors

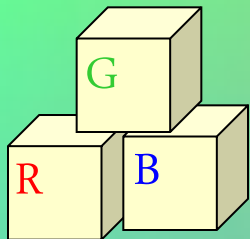


Accuracy of ΔE

RGB derived ΔE values



Correct ΔE values



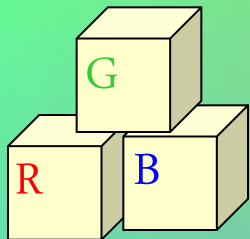
Accuracy of ΔE

False determination rate

Camera 1	3.2%
Camera 2	3.3%
Camera 3	2.6%
Status E	2.6%

When assessing pass/fail

*An RGB camera and a spectro
will agree 97% of the time*



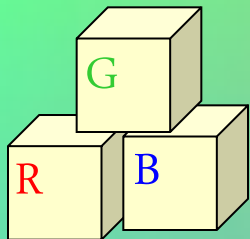
Conclusions from TAGA 2009

RGB camera can't
measure CIELAB
“accurately enough”.

You can't use an
RGB camera for
color OK.

RGB camera *can*
measure ΔE
“accurately enough”.

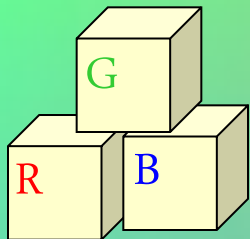
You *can* use an
RGB camera for
production run.



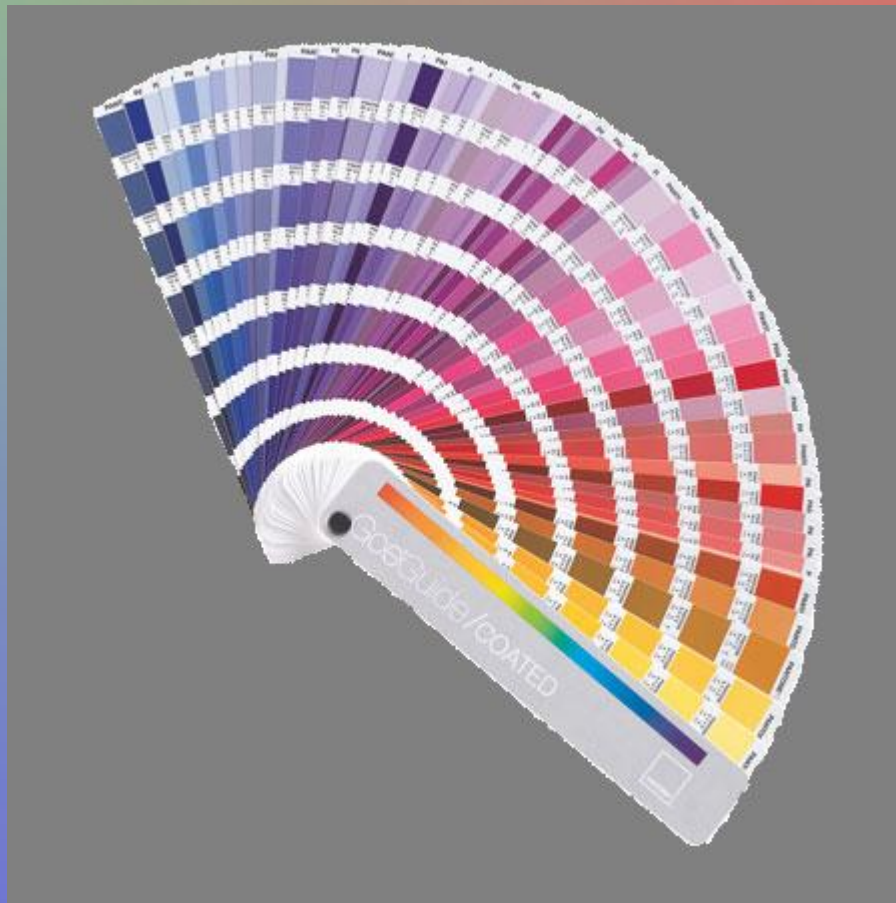
What about specialty colors?

The TAGA paper
tested CMYK

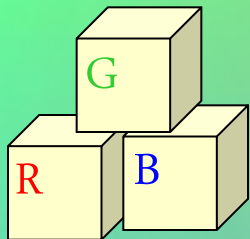
Will Pantone work
the same?



What about specialty colors?

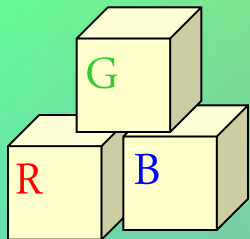


I started with
the spectra of 1,124 Pantone colors



What about specialty colors?

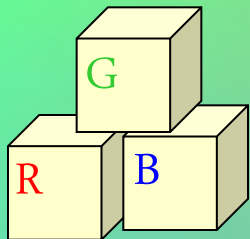
I developed an
RGB \rightarrow CIELAB transform
for these inks



Specialty colors - CIELAB

	CMYK	Set	Pantone	Set
	Mean ΔE	95 th %	Mean ΔE	95 %
Camera 1	1.8	4.5	3.6	8.9
Camera 2	2.3	5.4	4.8	14.0
Camera 3	1.8	4.3	4.4	10.0
Status E	1.5	3.2	4.2	10.2

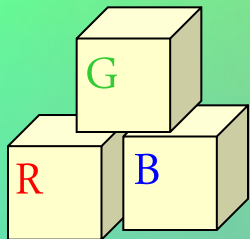
CIELAB accuracy –
not so good



What about specialty colors?

I repeated the
CMYK ΔE test

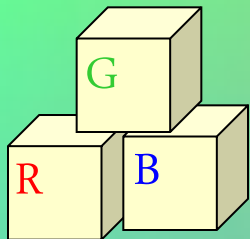
Only with Pantone



What about specialty colors?

	CMYK	Set	Pantone	Set
	Mean ΔE	95 th %	Mean ΔE	95 %
Camera 1	0.16	0.52	0.21	0.90
Camera 2	0.22	0.72	0.49	2.29
Camera 3	0.20	0.61	0.22	0.91
Status E	0.17	0.52	0.19	0.83

ΔE accuracy –
not too bad



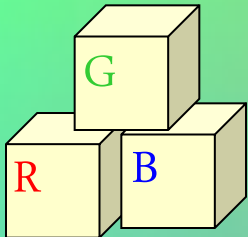
Conclusions for Pantone Inks

RGB camera can't
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You can't use an
RGB camera for
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You *can* use an
RGB camera for
production run.



Conclusions for CMYK inks

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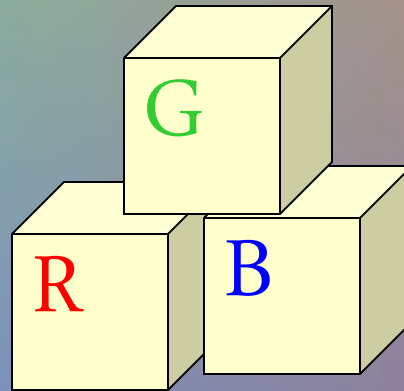
You *can* use an
RGB camera for
production run.

Conclusion

RGB cameras can be used
to measure color

... but you have to understand
the limitations.

Thank you!



John Seymour
Principal Engineer - Research
QuadTech