Copper Reds

	Oxblood Red	Purple Glaze	Vegas Red	Lipstick Purple	Coleman's Red
Gerstley Borate	13.27	4.97	8.29	5.17	10.8
Whiting	10.46	7.96	8	7.83	15.73
Barium Carbonate		4.98	4.14	2.58	
Dolomite		4.97	8.29	5.17	
Zinc Oxide		2.49	1.66	1.04	
Soda Ash				3.48	
Custer Feldspar	9.18	49.75	39.8	38.98	15.57
Nepheline Syenite	42.35				20.43
EPK	2.04		2.21	1.04	1.48
Silica Imsil A25	22.7				
Silica 200 mesh		24.88	24.54	29.58	36
Tin Oxide	1.7	1	2.49	2.26	1.72
Copper Carbonate	0.26	1.99	0.5	0.35	0.43
Cobalt Carbonate		0.24			
Yellow Iron Oxide			0.05		
Red Iron Oxide				0.04	
Rutile				2.33	
	McWhinnie Copper Red	**Pinnell Orange Red**	**Ron Roy** Revised Copper	**Ron Roy** Adjusted Copper	**Prange Red**
Gerstley Borate		14.2			
Whiting	13.54	9.3	15	15	
Zinc Oxide		1.7			
Magnesium Carb.	3.12				
Custer Feldspar	52.08				
Ferro frit 3278			17	17	
Ferro frit 3124					81.73
Nepheline Syenite		47.3			
Kona F4			34	34	
EPK			8		
OM-4				12	8.17
Bentonite					2.94
Silica 200 mesh	31.25	27.5	26	24	10.1
Tin Oxide	3.12	1	1	1	8.17
Copper Carbonate	2	0.3			3
Cupric Oxide			0.2	0.2	
	Hendley #1	**Hendley #2**	**Hendley #3**	**Hendley #4**	**Hendley #5**
Gerstley Borate	9	9	9	9	9
Whiting	8	9	11	10	12
Zinc Oxide	2	2			
Strontium Carb.		3	3		
Custer Feldspar	45	45	45	45	45
Talc	5.5	6	6	5.5	6
Barium Carb.	4.5			4.5	
EPK	2	2	2	2	3
Silica	21.5	21.5	21.5	21.5	22.5
Bentonite	2.5	2.5	2.5	2.5	2.5
Tin Oxide	2	2	2	2	2
Copper Carbonate	0.8	0.8	0.8	0.8	0.8

	Copper Red 1	**Copper Red 2**	**Copper Red 3**	**Copper Red 4**	**Copper Red 5**
Nepheline Syenite	65				35
Custer Feldspar		50	35	55	
Cornwall Stone			35		
Whiting		20	15		10
Wollastonite	20				
Gerstley Borate	10	10			10
Barium Carbonate				25	
OM-4 ball clay	5				
EPK		5	15	10	15
Silica		15		10	30
Tin Oxide	2	2	2	2	2
Copper Carb.	.4	.4	.4	.4	.4
	Copper Red 6	**Copper Red 7**	**Andreson Flambe**	**Andreson Chun Red**	**Andreson #1 Copper Red**
Nepheline Syenite	35	45			
Custer Feldspar			36.69	37.4	42.39
Whiting		15	2.29	12.7	2.65
Gerstley Borate			7.64		8.83
Zinc Oxide			1		1.77
Barium Carbonate	25		3.82	9.9	4.41
Dolomite	15		7.64	6.2	8.83
EPK	10	5	12.74	15.5	1.47
Silica	10	20	22.93		26.5
Petalite	5				
Borax frit		15			
Tin Oxide	2	2	2.29	1	2.65
Copper Carbonate	.4	.4	0.38	1	0.5
Red Iron Oxide			1.27	0.5	
Titanium Dioxide				1.3	
Old Coleman Contributions	**Copper Red 1**	**Copper Red 2**	**Copper Red 3**	**Copper Red 4 - 5**	**Copper Red 6**
Nepheline Syenite	17.17		25	20.00 - 16.14	
Kingman Feldspar	17.17	51.8	25	15.24 - 15.00	45.33
Whiting	15.45	8.75	2.5	15.40 - 0	9.93
Gerstley Borate		6.5	17.5	10.57 - 14.10	4.8
Zinc Oxide		2.2		0 - 8.27	0.67
Barium Carbonate			10	0 - 6.70	4.57
Dolomite		2.3			3.33
EPK				1.45 - 0	3.3
Silica	34.33	25.55	25	35.24 - 29.36	25.8
Soda Ash	12.88				
Talc				0 - 6.43	
Bentonite	0.86				
Tin Oxide	1.72	1	1	1.68 - 1.50	1.93
Copper Carbonate	0.43	1	1	.42 - .200	0.33
Red Iron Oxide		0.9	0.5		0.16

McKinnel Red 9/10

Custer	47
Whiting	13
Talc	3.5
Zinc ox	4.5
EPK	5.5
Frit 3110	9
Copper carb	1%
Bentonite	3%

Hillery's Red Glaze (Cone 10, reduction)

Barium Carbonate	8.8%
Colemanite	8.8
Dolomite	8.8
Whiting	2.7
Feldspar	42.5
Bentonite	1.8
Flint	26.6
	100.0%
Add: Tin Oxide	2.7%
Zinc Oxide	1.8%
Copper Carbonate	0.4%

Caitlin's Copper Red #11 Glaze

(Cone 10, reduction)

Colemanite	10.80
Whiting	15.73
Kona F-4 Feldspar	15.57
Nepheline Syenite	20.43
English China Clay	1.48
Flint	35.99
	100.00%
Add: Tin Oxide	1.72%
Copper Carbonate	0.42%

A vibrant red that may turn blue, green or purple where thick; runs when thick.

Coleman Vegas Red Glaze

(Cone 8–10, reduction)

Barium Carbonate	2.55%
Dolomite	5.61
Gerstley Borate	9.18
Whiting	8.68
Custer Feldspar	53.57
EPK (Edgar Plastic Kaolin)	2.55
Silica (Flint)	17.86
	100.00%
Add: Copper Carbonate	0.41%
Tin Oxide	2.04%
Titanium Dioxide	0.10%
Yellow Iron Oxide	0.10%
Zinc Oxide	1.02%

A beautiful oxblood with purple undertones.

Copper Glaze #1

(Cone 9–10, reduction)

Barium Carbonate	2.00%
Whiting	13.00
Zinc Oxide	4.00
Feldspar	52.00
Frit 3134 (Ferro)	6.00
English China Clay	5.00
Flint	18.00
	100.00%
Add: Copper Carbonate	0.25–0.50%
Tin Oxide	0.50–1.00%

Copper Glaze #2

(Cone 9–10, reduction)

Barium Carbonate	6.00%
Talc	2.00
Whiting	14.00
Zinc Oxide	2.00
Nepheline Syenite	43.00
English China Clay	4.00
Flint	29.00
	100.00%
Add: Copper Carbonate	0.25–0.50%
Tin Oxide	0.50–1.00%

Copper Glaze #3

(Cone 9–10, reduction)

Gerstley Borate	10.00%
Whiting	15.00
Zinc Oxide	2.50
Feldspar	15.00
Nepheline Syenite	20.00
English China Clay	2.50
Flint	35.00
	100.00%
Add: Copper Carbonate	0.25–0.50%
Tin Oxide	0.50–1.00%

The tin oxide addition should equal twice the amount of copper carbonate

Krator Red cone 9/10

Ball Clay	90
Whiting	185
Flint	270
Custer	360
Kona F-4	50
EPK	25
Dolomite	20
Bentonite	3%
for Lt. Red//Copper carb	0.5-1%
for Dk. Red//Copper carb	3%

PETE'S RED

Custer Feldspar	73
Gerstley Borate	10
Whiting	12
Flint	5
	100
Tin	1
Copper Carbonate	.3

ITO RED

Custer Feldspar	500
Ferro Frit 3134	50
Dolomite	50
Whiting	80
Barium Carbonate	50
Zinc Oxide	20
Silica	250
Macaloid	10
Tin oxide	20
Copper carbonate	5

#10 CHUN BASE Cone 1[illegible]

JIM SULLIVAN

Feldspar	144
Silica	9
Kaolin	6
Zinc	6
Whiting	4
Dolomite	30
Barium Carbonate	15
A. Red With Blue	
Colmanite	10%
CuCo3	5%
Tin	3%
B. Violet Red	
Zinc	5%
Colemanite	5%
Whiting	5%
CuCo3	.5
Tin	3%
C. Cherry Red	
Baruim	5%
Colemanite	5%
CuCo3	.5
Tin	3

Chun Base

Feldspar	144
Silica	9
Kaolin	6
Zinc Oxide	6
Whiting	4
Dolomite	30
Barium Carbonate	15

Red Blue	
Gerstley Borate	10%
Copper Carbonate	5%
Tin Oxide	3%
Violet Red	
Zinc Oxide	5%
Gerstley Borate	5%
Whiting	5%
Copper Carbonate	0.50%
Tin Oxide	3%
Cherry Red	
Barium Carbonate	8%
Gerstley borate	5%
Copper Carbonate	0.50%
Tin Oxide	3%

Candy Red

Cone 10 Reduction

used by Boomer Moore

Nepheline Syenite	42.3%
Custer Feldspar	9.2
Edgar Plastic Kaolin	2.0
Silica	22.7
Gerstley Borate	13.3
Whiting	10.5
TOTAL:	100.0%
add Copper Carbonate	0.3%
Zircopax	1.2%

This glaze is glossy copper red after firing to cone in a salt kiln. Moore uses a sandblaster to dull th surface and enlarge and emphasize the crazing on glaze surface, which creates a weathered surface.

RED #43 COPPER RED

Ferro Frit #3191	13.00
Feldspar	44.00
Whiting	14.00
Kaolin	3.00
Silica Flint	25.00
Tin Oxide	1.00
	100.00
Add:	
Copper carbonate	.2%

OXBLOOD RED cone cone 9-10

Nepheline Syenite	42
Custer Feldspar	9
Kaolin	2
Silica	23
Colemanite	13
Whiting	11
Black Copper Oxide	3
Tin Oxide	1
Bentonite	3

KEATOR RED cone 9-10

Ball Clay	90
Whiting	185
Silica	270
Custer Feldspar	360
Kona F-4 Feldspar	50
F.P.K.	25
Dolomite	20
Bentonite	3%

light red 1-½% copper carbonate
dark red 3% copper carbonate

Copper Red

Talc	4.21
Whiting	15.79
Soda Feldspar	55.79
Edgar plastic Kaolin	6.32
Flint	17.89
	100%
Tin Oxide	10.53
Copper Oxide	3.16
Silicon Carbide	3.16

Lehman Red

Dolomite	12
Strontium Carbonate	6
Whiting	8
Nephaline Syenite	37
EPK	2
Flint	35
	100%
Tin Oxide	3%
Copper Carbonate	0.50%

Barium Reduction Red Glaze

(Cone 10, reduction)

Barium Carbonate	32%
Custer Feldspar	42
Frit 3124 (Ferro)	6
Kaolin	8
Flint	12
	100%
Add: Tin Oxide	2%
Copper Carbonate	1%
Bentonite	1%

Dark Red Glaze

(Cone 10, reduction)

Bone Ash	14.77%
Magnesium Carbonate	14.77
Kona F-4 Feldspar	61.37
Kaolin	9.09
	100.00%
Add: Red Iron Oxide	9.09%
Bentonite	1.70%

Staley Red to Green

Custer	50
whiting	15
EPK	13
Dolomite	2
Flint	20
copper carb	8
iron ox.	1
bent	2

Lucian's Red cone 9 R

Custer Feldspar	720.
Colemanite	150.
Dolomite	150.
Whiting	45.
Zinc Oxide	30.
Barium Carbonate	75.
E.P.K.	25.
Flint	450.
Tin Oxide	45.
Copper Carbonate	8.5
	1698.5

RED #19 Cone 10

Frit 3124	45
Feldspar	104
Silica	118
Whiting	61.6
EPK Kaolin	19.2
Kentucky Ball #4	22.4
Soda Ash	28.6
Barium Carbonate	16
Tin Oxide	4.4
Copper Carbonate	2
Lead	2

RED FLAMBÉ Cone 10

Feldspar	144
Kaolin	5
Silica	90
Whiting	9
Colemanite	30
Dolomite	30
Zinc	6
Barium Carbonate	15
Tin	9
Copper Carbonate	1.5

ERICS RED Cone 10

Gersley Borate (Colemanite)	30
Feldspar Custer	144
Kaolin EPK	5
Silica	90
Whiting	9
Dolomite	6
Barium Carbonite	15
Tin	9
Copper Carbonate	3.3
Red Iron Oxide	5

Copper Red #18 Glaze
(Cone 9–10, reduction)

Gerstley Borate	8.13%
Whiting	12.70
Potash Feldspar (Custer)	79.17
	100.00%
Add: Tin Oxide	1.00%
Copper Carbonate	0.30%

Tusca cone 9/10 ox/red.

Nephy Sy	48
Barium carb	46
EPK	1
Flint	5
Bentonite	2
Add: Copper carb	4%
for Jade Green//Copper carb	2%
Chrome	1%

Blood Red cone 9/10

Ball Clay	25
Borax	25
Frit 3110	40
Copper carb	10

Willy Hillix cone 9/10 red.

Nephy Sy	25
Flint	14
Whiting	12
EPK	7
Bentonite	1.5
Copper carb	0.5
Copper ox (black)	2.5

Matte, Opaque.

Copper Red cone 9/10

Nephy Sy	40
Whiting	18
Flint	40
Borax	12
Tin ox	2%
Copper carb	0.5%
Bentonite	3%

Red Crystal Glaze
(Cone 9)

Barium Carbonate	40.0%
Zinc Oxide	15.0
Nepheline Syenite	35.0
Calcined Kaolin	5.0
Flint	5.0
	100.0%
Add: Black Nickel Oxide	1.5%

For a turquoise variation, replace the black nickel oxide with 2.5% copper carbonate.

Vivika's Strawberry Glaze
(Cone 10, reduction)

Gerstley Borate	13.93%
Dolomite	9.63
Whiting	2.77
Custer Feldspar	44.06
Edgar Plastic Kaolin (EPK)	1.84
Flint	27.77
	100.00%
Add: Tin Oxide	3.07%
Copper Carbonate	1.02%

COPPER RED cone 9-10

Nepheline Syenite	40
Whiting	18
Silica	40
Borax	12
Tin Oxide	2%
Copper Carbonate	½%
Bentonite	3%

McKINNEL RED cone 9-10

Custer Feldspar	47
Whiting	13
Talc	3.5
Zinc Oxide	4.5
Kaolin	5.5
Silica	15
Frit 3110	9
Copper Carbonate	1%
Bentonite	3%

MAMO COPPER RED cone 9-10

Nepheline Syenite	35
Whiting	30
E.P.K.	20
Zinc Oxide	10
Lithium Carbonate	2
Silica	38
Iron	½%
Copper Carbonate	½%
Bentonite	3%

for celadon add 1% red iron oxide to ba

Copper Red Glaze
(Cone 9–10, reduction)

Barium Carbonate	5%
Whiting	10
Frit 3134 (Ferro)	16
Potash Feldspar	42
Kaolin	10
Flint	17
	100%
Add: Tin Oxide	2%
Copper Carbonate	1%

CERAMICS MONTHLY

Copper Red Glaze
(Cone 7–11, reduction)

Frit 3124 (Ferro)	81.7%
Tennessee Ball Clay	8.2
Flint	10.1
	100.0%
Add: Bentonite	2.9%
Tin Oxide	8.2%
Copper Carbonate	3.0%

REVISED STANDARD RED

NEPH. SY.	47.3
GERSTLEY BORATE	14.2
WHITING	9.3
FLINT	27.5
ZINC OX.	1.7
COPPER CARB.	0.3
TIN OXIDE	1.0

FLAMBE' RED	%
CUSTER FELDSPAR	73.8
GERSTLEY BORATE	10.2
WHITING	11.6
FLINT	5.0
COPPER CARB	0.3
TIN OXIDE	1.0

Copper Red Glaze
(Cone 9, reduction)

Gerstley Borate	5.0%
Whiting	6.0
Frit 3124 (Ferro)	25.3
Nepheline Syenite	35.4
Tennessee Ball Clay	3.0
Flint	25.3
	100.0%
Add: Tin Oxide	1.0%
Copper Carbonate	0.3%

Copper Red Cone 9-11 (from Walter Donald Kring)

Gerstley Borate 9.10
Whiting 14.27
Nepheline Syenite 44.26
G200 Potash Feldspar 6.20
EPK Kaolin 2.59
Flint 23.58
100.00%

Add:
Copper Carbonate 0.41%
Tin Oxide 1.04%

Ben Owen
Copper Red cone 9 to 10 (red.)
Nepheline syenite-25
Flint-14
Whiting-12
EPK-7
Bentonite-1.5
Copper carbonate-.5
Copper oxide-2.5

Tom Gray
Copper Red
G200-73.8%
Gertsley borate-10.2%
Whiting-11.1%
Flint-4.9%
Copper carb.-.35%
Tin oxide-1%

Copper Red
Gertsley borate-8%
Whiting-15%
Nepheline syenite-13%
EPK-9%
Flint-30%
G200-25%
Tin oxide-2%
Copper carbonate-1.5%

Pablo's Red

Custer Spar 46.8
Flint 20.0
EPK 2.5
Whiting 8.3
Gerstley 13.7
Zinc Oxide 4.0
Dolomite 6.0
Tin Oxide 3.0
Copper Carbonate 1.5
Ferric Oxide 0.5

Purple (from Walter Donald Kring)

Dolomite 9.40
Gerstley Borate 13.60
Whiting 2.70
Zinc Oxide 1.80
G-200 Potash Feldspar 43.60
EPK Kaolin 1.80
Flint 27.10
100.00%

Add:
Cobalt Carbonate 0.05%
Copper Carbonate 0.50%
Tin Oxide 3.00%

Copper Red Cone 9-11 (from Dick Lehman)

Dolomite 12.0
Strontium Carbonate 6.0
Whiting 8.0
Nepheline Syenite 37.0
EPK Kaolin 2.0
Flint 35.0
100.00%

Add:
Tin Oxide 3.0
Copper Carbonate 0.5

Copper Glaze #1
(Cone 9–10, reduction)

Barium Carbonate	2.00%
Whiting	13.00
Zinc Oxide	4.00
Feldspar G 200	52.00
Frit 3134 (Ferro)	6.00
~~English China Clay~~ EPK	5.00
Flint	18.00
	100.00%
Add: Copper Carbonate	0.25–0.50%
Tin Oxide	0.50–1.00%

Copper Glaze #2
(Cone 9–10, reduction)

Barium Carbonate	6.00%
Talc 2882	2.00
Whiting	14.00
Zinc Oxide	2.00
Nepheline Syenite	43.00
~~English China Clay~~ EPK	4.00
Flint	29.00
	100.00%
Add: Copper Carbonate	0.25–0.50%
Tin Oxide	0.50–1.00%

Copper Glaze #3
(Cone 9–10, reduction)

Gerstley Borate	10.00%
Whiting	15.00
Zinc Oxide	2.50
Feldspar G-200	15.00
Nepheline Syenite	20.00
~~English China Clay~~ EPK	2.50
Flint	35.00
	100.00%
Add: Copper Carbonate	0.25–0.50%
Tin Oxide	0.50–1.00%

Δ 10 Reduction Glazes

Copper Red Glaze Formula Δ10 Reduction – add 1% Copper Carb., 1% Tin, 1% Iron for all 20 glazes

1.
34g Cornwall Stone
28g Borax
1g Soda Ash
12g EPK
7g Whiting
18g Silica

2.
42g Custer
16g Colemanite
1g Zinc
2g Barium
4g Talc
2g EPK
5g Whiting
28g Silica

3.
47g Custer Feldspar
3g Whiting
3g EPK
19g Colemanite
11g Barium
17g Silica

4.
11g Frit 3124
25g Custer Feldspar
15g Whiting
5g EPK
5g OM4 Ball
7g Soda Ash
4g Barium
28g Silica

5.
54g Custer
5g Colemanite
2g Dolomite
9g Whiting
2g Zinc
1g EPK
27g Silica

6.
29g Nepheline Syenite
28g Frit 3269
6g Whiting
4g EPK
33g Silica
+1% Macaloid

7.
29g Nepheline Syenite
28g Frit 3110
6g Whiting
4g EPK
33g Silica
+1% Macaloid

8.
37g Custer Feldspar
14g Whiting
5g Barium
2g Zinc
6g EPK
34g Silica

9.
43g Nepheline Syenite
14g Whiting
5g Zinc
4g Talc
5g EPK
29g Silica

10.
78g Custer Feldspar
10g Colemanite
12g Whiting
+1% Macaloid

11.
24g Frit 3124
37g Custer Feldspar
3g Whiting
5g Colemanite
7g OM4
24g Silica

No. 3 (c/8-10)	
Kingman feldspar	25.0
Silica	25.0
Nepheline syenite	25.0
Colemanite	17.5
Barium carbonate	10.0
Whiting	2.5
Copper carbonate	1.0
Tin oxide	1.0
Red iron oxide	.5

No. 4 (c/9-10)	
Nepheline syenite	20.00
Kingman feldspar	15.24
Silica	35.24
Whiting	15.40
Colemanite	10.57
Tin oxide	1.68
EPK china clay	1.45
Copper carbonate	.42

No. 5 (c/9-10)	
Nepheline syenite	16.14
Kingman feldspar	15.00
Silica	29.36
Colemanite	14.10
Zinc oxide	8.27
Barium carbonate	6.70
Talc	6.43
Copper carbonate	2.00
Tin oxide	1.50

↑
COLEMAN'S

No. 1 (c/9-10)	
Kingman feldspar	40.0
Silica	80.0
Nepheline syenite	40.0
Soda ash	30.0
Whiting	36.0
Tin oxide	4.0
Bentonite	2.0
Copper carbonate	1.0

No. 2 (c/9-10)	
Kingman feldspar	51.80
Silica	25.55
Whiting	8.75
Colemanite	6.50
Dolomite	2.30
Zinc oxide	2.20
Tin oxide	1.00
Copper carbonate	1.00
Red iron oxide	.90

No. 6 (c/9-10)	
Kingman feldspar	136.0
Silica	77.4
Whiting	29.8
Tin oxide	5.8
China clay	9.9
Barium carbonate	13.7
Dolomite	10.0
Zinc oxide	2.0
Copper carbonate	1.0
Iron oxide	.5
Colemanite	14.4

DAVID LEACH
COPPER RED Δ9

BORAX FRITT	15
F-4 SPAR	45
WHITING	15
CHINA CLAY (EPK)	05
FLINT	20
TIN OXIDE	05
COPPER CARB.	0.5
BENTONITE	1.0

Oxblood Red cone 9/10

Nephy Sy..........................42
Custer...............................9
EPK..................................2
Flint...............................23
Gerstly Borate......................13
Whiting.............................11
Blk Copper ox........................3
Tin ox...............................1
Bentonite............................3

T.C. VEGAS RED:

Custer Feldspar	39.80	3.600 g
EPK	2.21	200
200 mesh silica	24.54	2.220
Whiting	8	725
Gerstley Borate	8.29	750
Dolomite	8.29	750
Zinc Oxide	1.66	150
Barium Carb.	4.14	375
Tin Oxide	2.49	225
Copper Carb.	.50	45
Yellow Iron Oxide	.05	5

Copper Red Glaze
(Cone 7–11, reduction)

Frit 3124 (Ferro)	81.73%
Tennessee Ball Clay	8.17
Flint	10.10
	100.00%
Add: Tin Oxide	8.17%
Copper Carbonate	3.00%
Bentonite	2.94%

Copper Red #17

Custer Feldspar	440	8.47
EPK	20	0.38
Silica	270	5.19
Whiting	30	0.57
Colemenite	140	2.69
Dolomite	80	1.52
Zinc Oxide	20	0.38
Tin Oxide	30	0.57
Copper Carbonate	10	0.19
		20lbs.

Copper Red Flambe

Feldspar	144	8.73
Kaolin	5	0.3
Silica	90	5.44
Whiting	9	0.54
Gerstley Borate	30	1.8
Dolomite	30	1.8
Zinc Oxide	6	0.36
Barium Carbonate	15	0.9
Tin Oxide	9	0.54
Copper Carbonate	1.5	0.09
		20lbs

Copper Grape

Barium Carbonate	510	0.96
Dolomite	510	0.96
Whiting	817	1.54
Gerstley Borate	510	0.96
Feldspar	5102	9.66
Flint	2551	4.81
Copper Carbonate	204	0.38
Cobalt Carbonate	26	0.04
Tin Oxide	102	0.19
Zinc Oxide	255	0.48
		20lbs.

Peach Bloom

Nephaline Syenite	28	5.6
Colemenite	18	3.6
Dolomite	13	2.6
Silica	40	8
Tin Oxide	1	0.2
	100%	20lbs.
Copper Carbonate	1%	0.2
Yellow Ochre	1%	0.2

40	SPAR – 20N.S/20C
26	SILICA
8	DOLO
8	GERST.
2	WHITING
1	EPK
10	BARIUM CARB.
2	ZINC
3	TIN
1	COP CARB.

ON-MODE RED ▲1

RED #44 COPPER RED REDUCT

Cornwall Stone	27.90
Silica Flint	32.50
Zinc Oxide	4.00
Barium Carbonate	9.30
Soda Ash	4.30
*Borax	22.00
	100.00
Add:	
Copper Carbonate	2.0%
Tin Oxide	2.0%

RED #45 BINN'S REDUCTION R

Feldspar	34.30
Silica Flint	34.30
Colemanite	4.20
Whiting	12.90
Zinc Oxide	.50
*Bentonite	1.00
Frit #25	12.80
	100.00
Add:	
Tin Oxide	1.19%
Red Iron Oxide	.2%
Copper Carbonate	.5%

RED #46 SUPER RED

Feldspar	53.70
Kaolin	1.90
Silica Flint	3.40
Whiting	10.80
Colemanite	11.20
Dolomite	11.20
Zinc Oxide	2.20
Barium Carbonate	5.60
	100.00
Add:	
Tin Oxide	3.3%
Copper Carbonate	.7%

RED #28 CHERRY RED TRANS

Feldspar	43.60
Kaolin	1.80
Silica Flint	27.30
Whiting	2.70
Dolomite	9.10
Colemanite	9.10
Zinc Oxide	1.80
Barium Carbonate	4.60
	100.00
Add:	
Copper Carbonate	.5%
Tin Oxide	3.0%

RED #41 JEFF'S RED GLAZE

Barium Carbonate	4.30
Colemanite	8.60
Dolomite	8.60
Whiting	8.30
Zinc Oxide	1.70
Feldspar	41.30
Kaolin	1.40
Silica Flint	25.80
	100.00
Add:	
Tin Oxide	2.6%
Copper Carbonate	0.5%

RED #42 SHINSHA COPPER RED

Feldspar	12.60
Kaolin	17.90
Barium Carbonate	28.00
Whiting	13.00
Silica Flint	28.50
	100.00
Add:	
Copper Carbonate	3.0%
Tin Oxide	3.0%

RED #36 COLEMAN RED GLAZE

Barium Carbonate	4.70
Colemanite	4.90
Dolomite	3.40
Whiting	10.20
Feldspar	46.70
Kaolin	3.40
Silica Flint	26.70
	100.00
Add:	
Tin Oxide	2.0%
Zinc Oxide	.75%
Copper Carbonate	.5%
Red Iron Oxide	.2%

Oxblood Red Glaze
(Cone 10, reduction)

Gerstley Borate	13.27%
Whiting	10.46
Custer Feldspar	9.18
Nepheline Syenite	42.35
Edgar Plastic Kaolin	2.04
Flint (IMSIL A 25)	22.70
	100.00%
Add: Tin Oxide	1.70%
Copper Carbonate	0.26%

For other glazes in his repertoire that are not prone to crazing, Tom uses 200-mesh flint:

RED #1 PORCELAIN BASE

Fedlspar	50.00
Whiting	17.50
Silica Flint	17.50
Zinc Oxide	15.00
	100.00
Add:	
Wickle Oxide	1.0%
Copper Oxide	3.0%

RED #47 COPPER RED

Feldspar	55.00
Silica Flint	18.00
Whiting	16.00
Kaolin	6.00
Talc	4.00
Zinc Oxide	1.00
	100.00
Add:	
Copper Carbonate	.30%

RED #48 JANE'S COPPER RED

Feldspar	44.90
Kaolin	11.90
Silica Flint	12.70
Whiting	22.00
Tin Oxide	8.50
	100.00
Add:	
Copper Carbonate	1.0%

RED #9 RED I

Feldspar	48.60
Whiting	2.90
Colemanite	20.00
Barium Carbonate	11.40
Silica Flint	17.10
Add:	100.00
Copper Carbonate	1.2%
Tin Oxide	1.2%

RED #4 G446 JOHN MASON'S RED

Feldspar	72.50
Colemanite	10.50
Whiting	7.20
Silica Flint	7.20
Tin Oxide	1.10
Copper Carbonate	1.10
	100.00

NOTE: Gloss, opaque
1 coat: red w/green highlights
2 coats: green w/red highlights

RED #5 G447 REDUCTION RED

Feldspar	51.80
Silica Flint	25.55
Whiting	8.75
Colemanite	6.50
Zinc Oxide	2.20
Tin Oxide	1.00
Copper Carbonate	1.00
Red Iron Oxide	.90
	100.00

NOTE: Gloss, opaque
1 & 2 coats: green w/red highlights

RED #6 G448 REDUCTION DARK RED

Feldspar	42.50
Silica Flint	25.00
Colemanite	17.50
Barium Carbonate	10.00
Whiting	2.50
Copper Carbonate	1.00
Tin Oxide	1.00
Red Iron Oxide	.50
	100.00

NOTE: Gloss, opaque
1 coat: deep red, green where thin
2 coats: deep red

RED #7 G449 REDUCTION BROKEN RED

Feldspar	35.24
Silica Flint	35.24
Whiting	15.40
Colemanite	10.57
Tin Oxide	1.68
Kaolin	1.45
Copper Carbonate	.42
	100.00

NOTE: Gloss, opaque
1 coat: deep red w/turquoise highlights
2 coats: broken turquoise w/red highlights

RED #8 G450 RED ML2A

Feldspar	31.14
Silica Flint	29.36
Colemanite	14.10
Zinc Oxide	8.27
Barium Carbonate	6.70
Talc	6.43
Copper Carbonate	2.00
Tin Oxide	1.50
	100.00

NOTE: Semi-gloss, opaque
1 & 2 coats: metalic deep green, some red highlights

RED #11 COPPER RED

Feldspar	55.20
Silica Flint	17.70
Whiting	15.60
Kaolin	6.30
Talc	4.20
Zinc Oxide	1.00
	100.00

RED #12 JOHN MASON" RED

Feldspar	74.10
Colemanite	11.10
Whiting	7.40
Silica Flint	7.40
Add:	100.00
Tin Oxide	1.0%
Copper Carbonate	1.0%

RED #33 RED

Feldspar	44.00
Kaolin	1.80
Silica Flint	27.40
Whiting	2.80
Colemanite	9.20
Dolomite	9.20
Zinc Oxide	2.80
Tin Oxide	2.80
Add:	100.00
Copper Carbonate	2.0%

RED #15 MARGY'S COPPER RED

Nepheline Syenite	31.30
*Borax	7.10
Dolomite	2.30
Whiting	11.30
Zinc Oxide	2.00
Kaolin	2.50
Silica Flint	40.50
Tin Oxide	3.00
Add: Copper 2.5%	100.00

RED #16 RED II

Silica Flint	32.60
Feldspar	32.60
*Borax	18.50
Whiting	14.70
Zinc Oxide	1.60
Add	100.00
Copper Carbonate	3.0%

RED #19 PEACH BLOSSOM #2

Nepheline Syenite	27.90
Colemanite	17.20
Dolomite	12.80
Silica Flint	42.10
Add:	100.00
Copper Carbonate	1.0%
Ocher	1.0%
Tin Oxide	1.0%

RED #20 RED

Feldspar	36.40
Silica Flint	36.40
*Borax	10.90
Whiting	16.30
Add:	100.00
Tin Oxide	2.0%
*Bentonite	1.0%

RED #21 RED

Silica Flint	33.10
Feldspar	33.10
Whiting	15.00
*Borax	18.80
Add:	100.00
Zinc Oxide	2.0%
Copper Carbonate	3.0%

RED #22-A RED

Feldspar	41.80
Silica Flint	25.00
Whiting	11.40
Barium Carbonate	8.30
Kaolin	2.70
Talc	2.70
Bones Ash	2.70
Tin Oxide	2.70
Add	100.00
Copper	1.0%

Coleman's Red Glaze
(Cone 10, reduction)

Colemanite	10.80%
Whiting	15.73
Custer Feldspar	15.56
Nepheline Syenite	20.43
Edgar Plastic Kaolin	1.48
Flint	36.00
	100.00%
Add: Tin Oxide	1.72%
Copper Carbonate	0.43%

Oxblood Red Glaze
(Cone 10, reduction)

Colemanite	13.27%
Whiting	10.46
Feldspar	9.18
Nepheline Syenite	42.35
Edgar Plastic Kaolin	2.04
Flint	22.70
	100.00%
Add: Tin Oxide	1.70%
Copper Oxide	0.26%

This glaze needs good reduction to turn red. I often mix it with Coleman's Red to produce the best red of all.

Lehman Red Glaze
(Cone 9–10, reduction)

Dolomite	12.0%
Strontium Carbonate	6.0
Whiting	8.0
Nepheline Syenite	37.0
Edgar Plastic Kaolin	2.0
Flint (325 mesh)	35.0
	100.0%
Add: Tin Oxide	3.0%
Copper Carbonate	0.5%

Copper Red Glaze
(Cone 10, reduction)

Talc	4.21%
Whiting	15.79
Soda Feldspar	55.79
Edgar Plastic Kaolin	6.32
Flint (325 mesh)	17.89
	100.00%
Add: Tin Oxide	10.53%
Zinc Oxide	5.26%
Copper Oxide	3.16%
Silicon Carbide	3.16%

Copper Red Glazes

by Tom Coleman

This article first appeared in *Studio Potter*, Volume 8, Number 1 (December 1979).

I've had a love affair with copper red glazes ever since I started making pots. The first red piece I remember seeing was an old Chinese jar in the Portland (Oregon) Art Museum. Since that day it has almost become a ritual with me to fire a red pot, or at least put a couple of tests in every kiln load. My potter friends sometimes questions my frequent use of red glazes. Most of them say copper reds are usually hard to achieve but once mastered, what more is there? And a few people tell me that red glazes are too flashy, or just plain boring, or that not enough happens on the surface of the pot. To me, however, a good red glaze has a multitude of colors and a richness unduplicated in any other glaze.

I was excited while loading the very first test formulae of copper red glazes I had found in an obscure ceramics manual. Thoughts of beautiful, sensual reds ran through my head during the firing. The next day, however, I was greeted with matt, liver-pink colors. Since then I've tried many formulae, with varying results, but it is my opinion that any formula is only as good as the manner in which it is fired.

In some of my earlier firings, I noticed that if reds were close enough to a lighter colored, shiny glaze, the copper would flash off and create a red blush on the pot next to it. Sometimes there would only be a small spot of red left on the original pot, while the rest of the pot would be clear white. Significantly, the red that remained always had the richest color. This led me to believe that the point where the copper in the glaze is almost all reduced off is where you achieve the best reds. This can happen only when the firing time and the amount of reduction are carefully controlled. The glaze formula one selects should be glossy at the peak of the firing, but need not be running off the pot to make a good red. One must be able to apply a red glaze fairly thickly so it can make it through the higher fire reduction periods without dissipating its copper content. There are all sorts of simple methods one can use to ease this problem:

1. Brush on iron oxide over the glaze. This will help seal the surface at high temperature.
2. Brush a thin solution of copper slip under the glaze. This will produce a barrier to hold in the copper.
3. Fire the pot in a sagger that has copper carbonate brushed on the inside of it. This works to keep the copper gasses flashing back on the pot.
4. Put a clear, slightly lower-firing glaze over the base red glaze. This acts in manner similar to the iron oxide but allows more color to come through.
5. Add a small amount of silicon carbide powder to the glaze. This creates an internal reduction that dissipates less rapidly.

Through all my experimentation, I've found that good results can be achieved in almost every firing by making the entire kiln load copper reds. This allows the copper in its gaseous state to flash from pot to pot and not just disappear up the stack. I use a small fourteen cubic foot gas kiln to fire my reds. Firing time from start to finish runs ten to twelve hours. This gives the carbon plenty of time to enter the glaze. After that I keep the kiln in a light-to-medium reduction for one hour, then fifteen minutes of oxidation. I repeat this process until large cone 8 goes down. Then I put the kiln into straight oxidation until cone 9 is flat. This clears the surface of all excess carbon. I find if this procedure is not followed, the glaze tends to have a smoky or muddy appearance. This firing cycle, combined with whatever glaze formula one chooses, should give a start on achieving a good copper red. Here are my copper red formulae, as well as a few of my friends' formulae:

No. 1 (c/9-10)	
Kingman feldspar	40.0
Silica	80.0
Nepheline syenite	40.0
Soda ash	30.0
Whiting	36.0
Tin oxide	4.0
Bentonite	2.0
Copper carbonate	1.0

No. 2 (c/9-10)	
Kingman feldspar	51.80
Silica	25.55
Whiting	8.75
Colemanite	6.50
Dolomite	2.30
Zinc oxide	2.20
Tin oxide	1.00
Copper carbonate	1.00
Red iron oxide	.90

No. 3 (c/8-10)	
Kingman feldspar	25.0
Silica	25.0
Nepheline syenite	25.0
Colemanite	17.5
Barium carbonate	10.0
Whiting	2.5
Copper carbonate	1.0
Tin oxide	1.0
Red iron oxide	.5

No. 4 (c/9-10)	
Nepheline syenite	20.00
Kingman feldspar	15.24
Silica	35.24
Whiting	15.40
Colemanite	10.57
Tin oxide	1.68
EPK china clay	1.45
Copper carbonate	.42

No. 5 (c/9-10)	
Nepheline syenite	16.14
Kingman feldspar	15.00
Silica	29.36
Colemanite	14.10
Zinc oxide	8.27
Barium carbonate	6.70
Talc	6.43
Copper carbonate	2.00
Tin oxide	1.50

No. 6 (c/9-10)	
Kingman feldspar	136.0
Silica	77.4
Whiting	29.8
Tin oxide	5.8
China clay	9.9
Barium carbonate	13.7
Dolomite	10.0
Zinc oxide	2.0
Copper carbonate	1.0
Iron oxide	.5
Colemanite	14.4

All my red glazes were tested on and then used over a white stoneware or porcelain clay. They could also be used over dark stoneware, but I find they develop a deeper richness in color over a light background. If one wants to become involved with a white clay, try brushing a layer of white slip over the darker clay. If these formulae have a firing range that is too high in temperature, or if they are not melting enough to produce a good red, try replacing some of the feldspar with nepheline syenite. If a glaze seems to be almost right, but too matte, and if adding more flux changes its composition too much, try dipping a thin layer of one's favorite celadon over the base red glaze for better results.

Copper Red glazes by Karl Platt

Red Copper (Cu) glazes are distinctive and have been highly prized in history - everyone's heard about the Chinese guy who died taking the "secret" to the grave with him, leaving the Emperor quite disgruntled.

Cu red glazes are based on adding Cu into the glaze as an oxide and then exposing it to a reducing firing. If a sample of the glaze is drawn from the kiln at full heat should show at most a light straw color and it may turn red on cooling. The red is produced on cooling by crystals that come out of solution with the glaze. The composition of these crystals that has been the source of controversy.

Up until 1960 or so it was held that the color was due to metallic copper crystals. Really, this was accepted as being quite obvious. Then came Atamaram and Prasad, who suggested that the red color was actually due to Cu2O (red copper oxide) crystals.

Atamaram and Prasad's paper makes for very interesting reading on a number of levels - I wish I had a copy of it here! Recognizing the difficulties had in making Cu Red, and the desirability of the color as used in glass bangles Indian women especially like, they set out to study and refine the parameters of Cu red development. In the course of their work they came to the Cu2O conclusion, but their work was criticized because they added large amounts of Cu (up to 5 wt%) to their glasses.

However, through their work they did obtain delicious and repeatable red glasses.

Behind Atamaram and Prasad came Rawson who showed that the color of Cu red was consistent with the results expected from what is known as the Mie Scattering Theory for Cu-metal. Mie theory predicts what wavelengths will be preferentially reflected from the metal surface. It's real complicated and we'll leave it to say only that the red Rawson found by measuring the spectrum of the red in his glasses gave results that were consistent the presence of Cu-metal.

Amal Paul, a guy no-one can say enough about, undertook to sort out the controversy about just what it was that made reduced Cu glasses red - Cu2O, Cu-metal or a mix if the two. He did his studies in a glass made of 30 Na2O and 70 B2O3 --- this does not represent either a useful glass or glaze, but it is easy to melt. No tin was added to the glass and the amount of Cu this glass will hold is very low-up to 0.13wt% Cu taken as metal.

Paul concluded that both Cu and Cu2O are present and the "better"-more pure - Cu reds were abundant in Cu2O.

Cu belongs to a group of metals known as the Nobel Metals. The Nobel Metals are Cu, Ag and Au. In this order they are progressively less likely to form oxides.

Recalling our discussion on Redox, [Editor: a discussion on Clayart about the mechanisms of oxidation and reduction] we can say that the outer electrons on these metals are progressively more rigidly held moving from copper to gold. Gold stays reduced, silver resists oxidation, and copper will go along and ditch an electron or two depending on the crowd it's in.

Cu oxides, of course, are well known. You can buy Ag2O from the chemical house, but apart from that it's not seen much - the film that develops on your Ag tableware is not predominantly oxide. Au oxide is never encountered in normal circumstances; this is the source of value in gold.

When Ag or Au are added to a glaze, it is not necessary to employ heavy reduction to produce metal atoms - Ag and Au would rather be metal atoms. There is a limit as to how many of these metal atoms can be in solution (colorless) with the glaze - naturally this limit is called the solubility limit. When this critical limit is exceeded, the excess metal atoms combine with their kind to form crystals.

These crystals of Ag or Au metal produce color in the glaze.

The color is determined by how these crystals are shaped, how they are distributed in the glaze/glass and their size. The number of metal atoms that can be held in solution with the glaze decreases as temperature decreases.

As the glaze cools metal crystals will develop -- Often tending toward being fewer and larger where big crystals form at the expense of little ones. However, the little crystals can also coagulate, and this affects the color observed.

The size of these crystals is on the order of 50-200 millimicrons -- +/- a little. If the crystals get large the glass looks like liver looks (tastes?) and is called livery. If you made livery glass/glaze, you blew it. Do not pass Go. No Doughnut. Call the dumpster man. We're not here to make livery rubies.

The color in glazes containing nobel metal crystals is mainly produced by the absorption of light by the metal crystals. Scattering effects have no role in producing the color unless the glass is livery. Big crystals scatter enough light to make the glaze appear opaque in reflected light and (densely) colored in transmitted light. We almost always look at rather than through glazes, so it is the reflected results which matter to us.

Crystallization occurs within a limited range of temperatures. Above some temperature there's too much thermal agitation to allow the metals to organize into crystals, and below some temperature the glaze will be too viscous to allow atoms to migrate towards a developing crystal. Hold this notion, it'll appear again.

Au (gold ruby) is very rarely used in Studio Ceramics. I can't think of anyone hand-rolling their own Au reds - if you're out there please stand-up.

There are, however, Au ruby overglazes and glass enamels commercially available. Most of these are based on soft fritted lead glass and they're not cheap - not because they have huge amounts of Au in them (there are very tiny amounts), but they're tough to make. There's nothing to preclude anyone from making Au ruby glazes except that errors are a little pricey in terms of time and providing for precision. In terms of cash cost, it's really not so terrible as the amount of gold needed is very small.

Au glass/glaze has its distinctive ruby color. Fenton's sells as "Cranberry" Glass. Apart from tableware Au red is often seen in colored sheet glass. There are (really beautiful) blue Au glasses which form when the conditions cause the Au crystals to become large-ish and very non-spherical.

Silver (Ag) can make almost any color in glaze if you know how to manipulate it, but usually it gives yellow. Ag is essentially never used in modern art Ceramics, but the ancients used it widely - especially the Persians who developed fantastic lustres after the collapse of Rome -- the artisans had to go somewhere.

By applying a paste of $AgNO_3$, Kaolin and a little $BaSO_4$ on the surface of bright soda-rich glazes and then refiring the pot to 1400 F/650C or so you can "stain" the glaze locally to nice effect.

Glassmakers use Ag quite often to develop a number of effects. These range from yellow glass to brown glass to a glass that is multicolored in reflected light, but yellow/amber in transmitted light. There are also silver glasses that develop a metallic sheen with reduction.

Essentially spherical crystals of Ag metal cause the yellow and brown glasses. If the color is non-uniform, the stuff the Ag is in is probably not uniform. When the glass turns brown it is also frequently turbid (milky). This is owing to having formed large and numerous crystals - scattering of incident light, and mushy absorption characteristics tending to longer (more red) wavelengths.

Multicolored effects seen in silver glasses\glazes are due to the development of non-spherical crystals. The mechanics of all of this are not, however, our concern here, but Peet mentioned these and I thought it would be worth a brief mention as these effects could also be developed in glazes as well.

Silver glazes have fantastic potential that is overlooked in Studio Ceramics. It is possible to produce any color in a very pure form using only silver. Accomplishing this is a delicate dance, but like Tango, the logic is clear. If you've managed to come to here without hitting the delete key, I'd like to solicit a few collaborators in elaborating Ag in decorative glazes.

But we're really interested in Cu-reds why all this about silver and gold? Well, the formation of Cu-reds follows the same lines in terms of the crystallization mechanics - oversaturation --> crystal formation --> growth or coagulation of the crystals. However, in the case of Cu it's not simply a matter of precipitating metal.

Cu can do a number of things when added to a glaze. In alkaline glazes it yields a very distinct blue color (Cu2O). In less alkaline glazes it's green. (CuO). This indicates the importance of composition on color development. Red, however, can be produced in almost any base glass.

In fact, Cu is quite sensitive to its chemical environment and I've found it to be a good and very handy indicator as to the acidity or basicity of a glaze - kind of a litmus test. Simply, if Cu is the only colorant in a glaze, and the glaze is fired in air, how blue it is gives a rough idea as to what you can expect from the glaze in terms of its many other chemistry sensitive colors.

You can't simply chuck Cu-oxide into any 'ole glaze and expect it to come out red. The following factors come into play:

Composition

The presence of tin oxide

Reduction

Cooling and sometimes reheating

In terms of composition, the glaze needs to be able to support the solution of Cu. To achieve this it needs to have things in it that are friendly to the presence of metal. The best of these is PbO - I can hear the gasps of horror now. Yes, that Godzilla of the Elements. Bismuth is another good option in some glazes, Zn helps and there is, of course, tin (Sn).

Sn does a couple things. First it improves the solubility of Cu. Metals, per se, aren't really very soluble in glaze and if you can't get the metal dissolved, it can't very well be precipitated in any organized fashion. Second, on cooling, Cu tends to attract Sn atoms from the glaze. These atoms sort of "coat" the crystals as they are developed and thus serves to control their size by limiting the attachment of further Cu atoms to the crystal. This behavior is that of a protective colloid and it is of great advantage. Because if the crystals get big, the glaze turns "livery" looking, and the doughnut remains elusive. Third, to the extent that Sn has limited solubility in SiO2 or B2O3 based glassy material, it probably also serves to provide nuclei on which the coloring crystals can grow.

Tin oxide is added to all practical non-lead Cu red glazes in amount way beyond what's necessary to promote good solution of Cu in the glaze - many compositions contain up to 4-wt%. Of course, if there's too much tin it doesn't all dissolve -- causing opacity. This may or may not be desirable.

Tin is volatile at high temperatures and a lot of it leaves the very thin glaze film by evaporation. Compensating this evaporation is important to how much tin will remain dissolved in the glaze. This explains the large amounts of SnO2 in many reported glaze compositions. Some kilns have turbulent atmospheres and a larger amount of evaporation would be anticipated in these circumstances. In glassmaking, if you melt in a covered pot, in which evaporation is not an issue (in most cases), the amounts of SnO_2 required seldom exceed 2 wt%.

If you use too little Sn to promote the solution, Cu will precipitate on the spot with dreadful results. This is one of the reasons that application of the glaze is so important and why really thin films often fail to develop a nice red - when red color forms at all in a tin depleted glaze, it often has the color of liver instead of a crisp red.

The amount of Cu necessary to develop a good red depends on how much of it can be dissolved. This depends on how much the glaze would dissolve on its own and how much this is improved by the presence of Sn. Many pottery glazes contain what I feel is a lot of Cu-oxide in the batch, but that's just an opinion. The best reds always contain the least amount of Cu. Reduction is the critical step in producing a nice Cu red.

Amal Paul's 30 Na_2O 70 B_2O_3 glass was melted in a little electric furnace with a strictly controlled reducing atmosphere - CO-CO_2 mixtures metered into the furnace with precision gear. He found that as the "amount" of reduction increased there is a level below which no red forms; a (point) range of reduction within which good reds developed and a point (range) above which the color is funky.

His conclusions were:

In reduction one wants to achieve an equilibrium which includes only Cu_2O (red copper oxide) and Cu-metal, with no CuO present. The amount of Cu-metal dissolved in the glaze is fixed by the glaze composition and the amount of Cu_2O present in the glaze is fixed by the atmosphere. It should be mentioned that by using the term Cu_2O it is not meant that molecules of Cu_2O are floating about in the glaze. On the contrary, it means that Cu^{+1} ions are in the glaze and that on cooling Cu_2O crystals (which are red) are formed. There is some degree of reduction at which Cu_2O solubility is at a maximum. This is the point you want to find.

If the reduction applied to the glaze is too weak CuO forms together with Cu_2O and Cu-metal. This is not where you want to be at all because at this level of reduction, the glaze will be unsaturated in Cu_2O and Cu-metal. As a result nothing will crystallize and you won't see any red. However, owing to poor mixing of the glaze batch it frequently happens that red patches develop in the presence of green CuO. This can be a nice effect.

If reduction is too strong an abundance of Cu metal is formed at the expense of Cu_2O, the glaze will precipitate Cu-metal on the spot, as its solubility will have been exceeded, and the color is murky. This is an important distinction between Cu red glazes and Cu red glasses. In an over-reduced glass the metal comes out of solution and sinks to the bottom of the crucible - often forming little beads that drill holes in the crucible. In glaze, the Cu metal can't wander away. Sometimes it manages to oxidize again depending on the firing conditions and it can also form a metallic film on the surface of the finished glaze. The extreme character of this behavior is widely exploited in raku.

The thermodynamic considerations of all of this are tedious, and it's not worth going into all of it here, but the sum results are:

In reduction you can produce three forms of Cu in the glaze. These are:
CuO, Cu_2O and Cu-metal.

The ideal degree of reduction will be a little different for each base glaze. I don't have time to crunch the numbers to give some precise fuel/air mix, but if someone else wants to go through it, feel free. In a little more absolute terms, you want to produce an oxygen pressure somewhere between 10^{-12} and 10^{-15} atmospheres. This corresponds to a CO/CO_2 ratio around $1/10^5$ - I pulled these numbers off of an Ellingham diagram, they were not calculated.

Of course, rich combustion yields Hydrogen, too, and this needs to be considered. Also, Ellingham diagrams say nothing about the "activity" of the metal/oxide in glaze and these effects can be profound.

Apart from applying heavy science to making Cu red glazes we all know that arriving at the best fuel/air ratio can, of course, be derived by trial and error - as has been done for millennia.

This takes us to the importance of having a stable combustion system with means for metering the amount of fuel and air entering the kiln. Precise combustion is elusive in natural draft kilns subject to wind, variable atmospheric pressure and so on. It can be achieved by experienced operators constantly tending the fires. High-pressure gas "venturi" burners will furnish better repeatability in natural draft kilns in all circumstances. Forced air combustion can be metered very precisely by metering orifices.

We should note again that oxygen analyzers cannot meter reduction - they are sensitive to the presence, not the absence of oxygen. As such other means, like metering orifices, or even a decent pressure gauge are preferred.

We've established that there is some degree of reduction at which the amount of Cu_2O is at a maximum and that this is where we will get the best color. Establishing this condition in the glaze can be done several ways. Some like to begin reduction early in the firing - around 1700 F or so and maintain this degree of reduction through the end of the firing. This is fine. Others like to reduce the pi$$ out of the kiln for a short time at high temperature. This can work, too, but it never goes as well as the former approach.

In very practical terms, a glaze film is really thin - usually way less than a millimeter. While glaze is usually pretty viscous stuff, it
doesn't take terribly long at high temperatures for equilibrium between Cu/Cu_2O and the atmosphere to be established. I'd suggest that firing in neutral conditions until the last couple or three hours of the firing, and then adding the necessary reduction will be a more economical approach to obtaining the best results. Three hours is plenty long enough to establish equilibrium. Moreover, really prolonged reduction has other affects which may not be desirable at all - like depleting the glaze surface of Na, messing with the body color in undesirable ways, deteriorating the kiln's refractories, and so on.

Re-oxidizing, as it were, can occur if the circumstances are right. Avoiding this can be done by cooling rapidly to 1,700 F or so. Maintaining reduction during cooling is sometimes necessary to control the redox balance in the glaze.

We know that the color is formed by the precipitation of Cu and Cu_2O crystals on cooling. Usually a kiln will cool slowly enough so that these crystals have plenty of time to form in the natural cooling of the kiln -- net cooling rates of 1-3 degrees F/minute are common. Cooling will be faster at first and then proceed at a progressively slower rate owing to the diminished temperature gradient between the interior of the kiln and the air.

There will be some temperature at which the crystallization rate is highest. Above this temperature the thermal agitation within the glaze is too great to permit crystals to organize and below it the viscosity of the glaze retards the progress of Cu or Cu^{+1} to developing crystals.

There will also be some temperature at which the precipitation of Cu_2O is at a maximum on cooling. If you find that temperature and hold it for a spell you get better reds.

There may be the weird instance where cooling was too fast and no color appears. In such a case one can reheat the pot to 1,600-1,800 F and the red will form - assuming you reduced correctly.

The presence of P_2O_5 lends to ruby formation and this was well known to potters in early civilizations. It has a reducing influence by its presence and it is highly insoluble in the host glaze. As a result P_2O_5 rich droplet regions will form within the glaze and these will promote development of the red crystals. An excess of P_2O_5 gives opalesence - this can be beautiful.

It would be useful to assemble and examine studio results a lot more carefully. There's a great deal of experimentation in the archives of the last 25 years we could probably learn something from.

Getting the quantities of Sn and Cu right is something that can be worked out using line-blend methods. Any well made shiny glaze will serve as a host for Cu Red. The maximum Sn and Cu you'd want to use are around 3%. Excellent Cu reds have been made with a lot less of both elements. Sn is typically add to the batch in larger amounts than Cu - 3:1 is a frequent ratio. The amount of Cu is fixed its solubility in the glaze - you want to use just enough. The minimum amount of Sn is that necessary to evade having it all evaporate.

The amount of Cu that crystallizes depends strictly on it's concentration. Less is usually more in Cu reds.

Someone else might have the patience to elaborate how this line-blend should go together. I'd do it on a triaxial in 5 divisions (20% increments) with the corners being: Neat glaze, 3% Cu, 3% Sn.

Make enough glaze to make 3 or 4 test tiles (of the same clay body) of each mixture and fire these in separate firings in the same place in the kiln. This'll give you an idea what the quality of the firing is like - assuming you made homogeneous glaze in the first place.

Adding SiC to the glaze to furnish reduction in electric kilns gives results ranging from moonscape to colorless glaze. In the main, it doesn't work real well....at all. You can also toss organic material into the kiln - I've always been amused by the use of mothballs - they work, but the stench.... Charcoal is a good alternative. You could, as well, be really anal and go out and get tanks of CO and CO2 to inject into the kiln. Talk to your welding gas supplier. And if you do this stuff, don't do it in a confined space.

Remember to do an oxidizing firing after reducing in the electric kiln to build up the Al2O3 film on your Kanthal elements. Nonetheless, element life will be diminished by reduction firings.

Elemental Si is something that should be tried as an in-glaze reducing agent. Maybe someone's already done it. It's cheap, widely available - especially to those who live near a steel works - and very potent in its effects. The advantages of Si as a reducing agent are several fold, but the big one it that you can melt with more correct combustion, and a few grams of Si has always been a lot cheaper than 6 or 7 hours of bad combustion.

Alright, I don't know about you, but I've had quite enough of all of this.