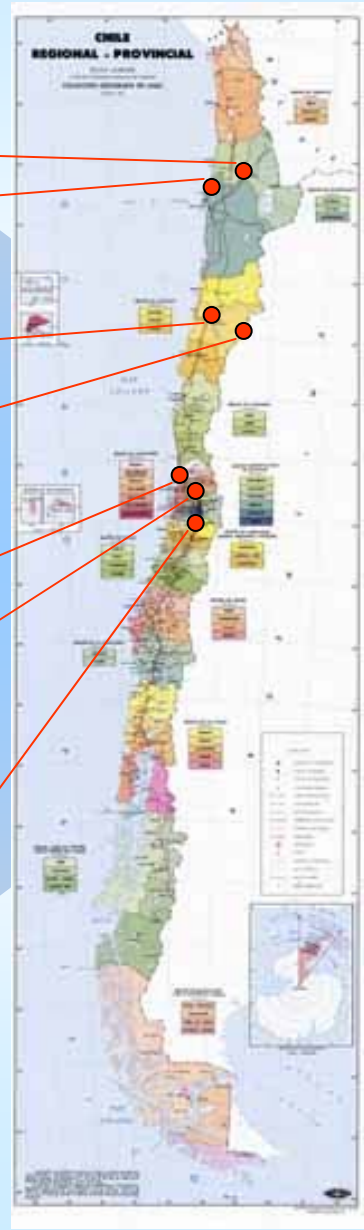
# An Update on Chilean Copper Smelters

ANGL AMERICAN CHILE

MINERA SUR ANDES Ltda.

# Chilean Smelters

| | |
|---|---|
| **Chuquicamata Smelter:** | Codelco Norte Division |
| **Altonorte Smelter:** | Noranda |
| **Paipote HVL Smelter:** | (ENAMI) Paipote |
| **Potrerillos Smelter:** | El Salvador Division |
| **Ventanas Smelter:** | Ventanas Division CODELCO (Ex – ENAMI) |
| **Chagres Smelter:** | Minera Sur Andes Ltda. MSA, AngloAmerican Group |
| **Caletones Smelter:** | El Teniente Division CODELCO |



# COPPER PRODUCTION CAPACITY IN CHILEAN SMELTERS

| COMPANY | SMELTER | ANUAL COPPER PRODUCTION MTPY COPPER |
|---|---|---|
| Codelco | Chuquicamata | 580,000 |
| Noranda | Altonorte | 290,000 |
| ENAMI | Paipote | 100,000 |
| Codelco | Potrerillos | 200,000 |
| MSA | Chagres | 185,000 |
| Codelco | Ventanas | 110,000 |
| Codelco | Caletones | 365,000 |
| TOTAL | | 1,830,000 |

# CONCENTRATE QUALITY

| FEED ANALYSIS | Codelco | Noranda | ENAMI | Codelco | MSA | Codelco | Codelco |
|---|---|---|---|---|---|---|---|
| CONCENTRATE | Chuquicamata | Altonorte | Paipote | Potrerillos | Chagres | Ventanas | Caletones |
| tspa | 1,650,000 | 800.000 | 330,000 | 680,000 | 610,000 | 420,000 | 1,600,000 |
| %Cu | 33.0 | 36.6 | 28-30 | 30.8 | 31 | 30.7 | 30.8 |
| % Fe | 20 | 15.0 | 28-30 | 23.0 | 22.4 | 25.3 | 26.5 |
| % S | 32.9 | 28.2 | 32-35 | 31.2 | 31 | 32.4 | 31.8 |
| % As | 0.83 | - | 0.06 | 0.31 | 0,08 | - | 0.19 |
| % SiO2 | 6.2 | - | 1.8-2.5 | 7.7 | 6.58 | 6.9 | 5.5 |
| % Sb | - | - | - | 0.04 | 0.005 | - | 0.23 |
| % Pb | 0.18 | - | - | 0.01 | 0.007 | - | 0.045 |
| % Zn | 1.28 | - | - | 0.22 | 0.03 | - | 0.22 |
| % Bi | 0.08 | - | - | 0.01 | - | - | - |
| % Mo | 0.19 | - | - | 0.17 | 0.09 | - | 0.15 |
| % Ni | 0.01 | - | - | 0.01 | - | - | 0.004 |
| Au g/t | 0.5 | - | - | 1.5 | - | - | - |
| Ag g/t | 110 | - | - | 75 | - | - | - |
| % H20 Wet Con | - | 8.42 | 7.5-9.0 | 8.0 | 10 | 8.6 | 8.5 |
| % H20 Dry Con | 0.2 | - | - | 0.2 | - | - | 0.2 |
| Mesh Size | 80% < 150 Mesh | - | 80% < 270 Mesh | 80% < 80 Mesh | 76% < 325 Mesh | 70% < 200Mesh | 70% < 325 Mesh |

# SMELTER / DIVISION FINAL PRODUCT

| COMPANY | SMELTER | SMELTER PRODUCT TYPE | ANODE ANALYSIS %Cu | DIVISION FINAL PRODUCT |
|---|---|---|---|---|
| Codelco | Chuquicamata | Anodes | 99.60 | Cathode |
| Noranda | Altonorte | Anodes | 99.65 | Anodes |
| ENAMI | Paipote | Anodes | 99.57 | Anodes |
| Codelco | Potrerillos | Anodes | 99.47 | Cathode |
| MSA | Chagres | Anodes | 99.75 | Anodes |
| Codelco | Ventanas | Anodes | 99.61 | Cathode |
| Codelco | Caletones | Anodes & Fire Refined Copper Ingots | 99.70<br>< 99.92 | Anodes & Fire Refined Copper Ingots |

# SMELTER WORK FORCE

| COMPANY | SMELTER | Number of Employees |
|---|---|---|
| Codelco | Chuquicamata | 800 |
| Noranda | Altonorte | 520 |
| ENAMI | Paipote | 500 |
| Codelco | Potrerillos | 400 |
| MSA | Chagres | 300 operations<br>200 maint. & servs. |
| Codelco | Ventanas | 230 operations<br>230 maintenance |
| Codelco | Caletones | 730 |

# SMELTER EMISSION REGULATIONS

| COMPANY | SMELTER | $SO_2$ ($ug/Nm^3$) | Arsenic Tpa As |
|---|---|---|---|
| Codelco | Chuquicamata | 1,000 (1h); 250 (1d); 80 (1y) | 400-800* |
| Noranda | Altonorte | 1,000 (1h); 250 (1d); 80 (1y) | 126 |
| ENAMI | Paipote | 1,000 (1h); 250 (1d); 80 (1y) | 34 |
| Codelco | Potrerillos | 1,000 (1h); 250 (1d); 80 (1y) | 150-800* |
| MSA | Chagres | 1,000 (1h); 250 (1d); 80 (1y) | 95 |
| Codelco | Ventanas | 1,000 (1h); 250 (1d); 80 (1y) | 120 |
| Codelco | Caletones | 700 (1h); 250 (1d); 60-80 (1y) | 375 |

*** Higher Limit Applies in case with no Human Settlements 8 km from Emission Source**

# SMELTER PERMISSIBLE AIR CONCENTRATION LIMITS IN WORKPLACE

| | Maximum Concentration Weakly Average | | Maximum Concentration Fifteen Min. Air Sample | |
|---|---|---|---|---|
| | ppm | $mg/m^3$ | ppm | $mg/m^3$ |
| Sulfur Dioxide | 1.6 | 4 | 5 | 13 |
| Arsenic | - | 0.0008 | - | - |
| Dust (total) | - | 8 | - | - |
| Dust (breathable fraction, PM-5) | - | 2.4 | - | - |

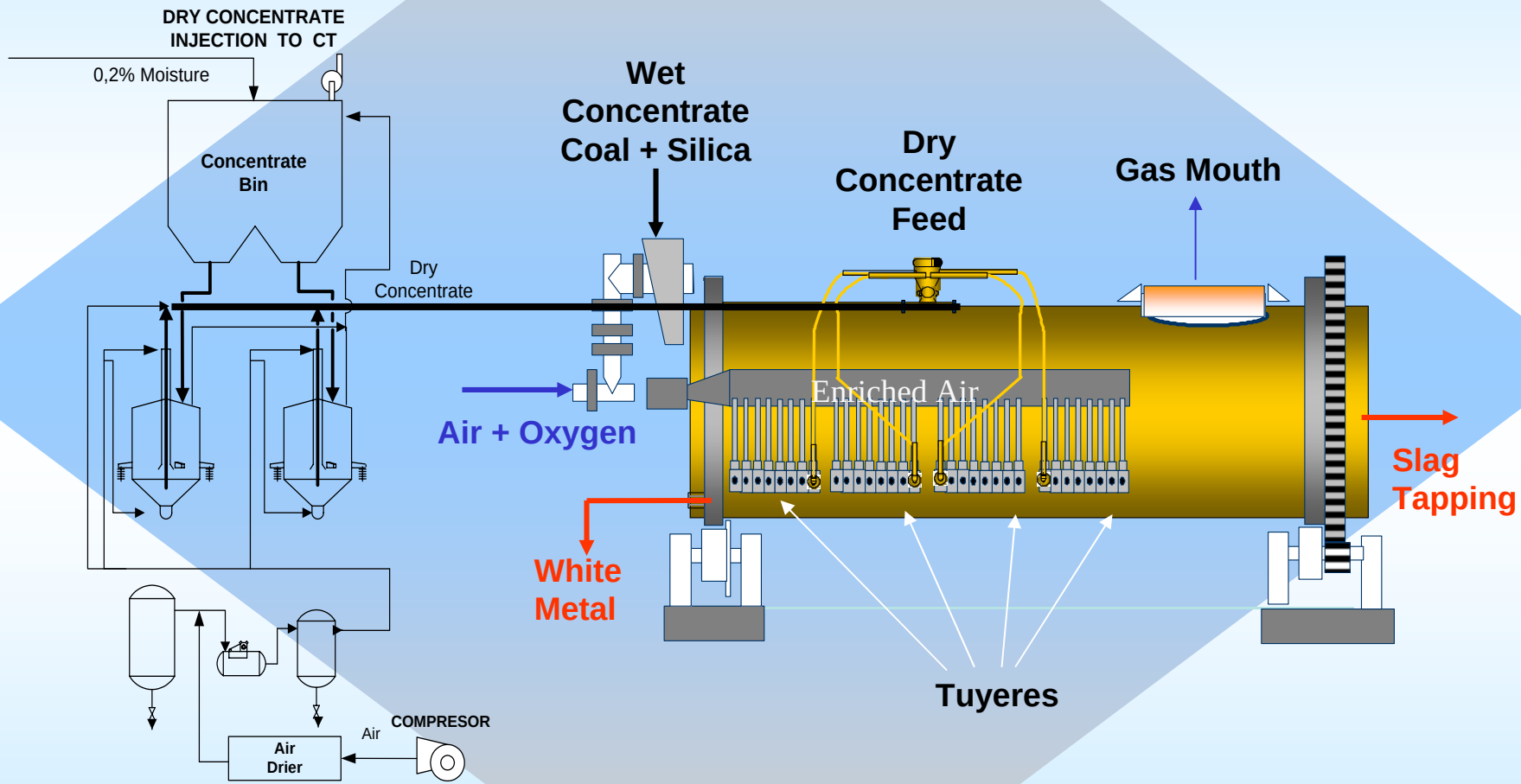
# SULPHURIC ACID

| COMPANY | SMELTER | ACID PRODUCTION | | | | | Product Grade | Plant Type |
|---|---|---|---|---|---|---|---|---|
| | | Source Gas | Number Acid Plants | Volume $Nm^3/h$ | MTPD | MTPY | H2SO4 % | |
| Codelco | Chuquicamata | SF+TC+PS | 3 | 465,000 | 4,590 | 1,560,000 | 98.5 | Single Absorption |
| Noranda | Altonorte | Continuous Reactor + PS | 2 | 260,000/ 300,000 | 2,400 | 816,000 | 97-98 | Double Absorption |
| ENAMI | Paipote | PS+TC | 2 | 50.000/ 80.000 | 300/580 | 102,000/ 197,000 | 98.5/ 98.5 | Sybetra/ Monsanto |
| Codelco | Potrerillos | TC+PS | 1 | 200,000 | 1,100 | 374,000 | 98 | Single Absorption |
| MSA | Chagres | SF+PS | 1 | 150,000 | 1,690 | 551,000 | 98 | Lurgi – Fenco Double Abs. |
| Codelco | Ventanas | TC+PS | 1 | 115,000 | 1,050 | 354,000 | 97.8 | Hugo Petersen |
| Codelco | Caletones | TC+PS | 2 | 162,000/ 258,000 | 1,500/ 2,350 | 510,000/ 110,000 | 98.5/ 98.5 | Single Absorption |
| TOTAL | | | 12 | 1,400,000/ 1,600,000 | 12,630/ 13,760 | 3,900,000/ 4,300,000 | | |

# SMELTER TECHNOLOGY

| | CODELCO | NORANDA | ENAMI | CODELCO | MSA | CODELCO | CODELCO |
|---|---|---|---|---|---|---|---|
| | Chuquicamata | Altonorte | Paipote | Potrerillos | Chagres | Ventanas | Caletones |
| SMELTING | Flash Smelting + Teniente Converter | Continuous Reactor | Teniente Converter | Teniente Converter | Flash Furnace | Teniente Converter | 2 Teniente Converter |
| CONVERTING | 4 Peirce Smith | 3 Peirce Smith | 1 Peirce Smith | 3 Peirce Smith | 4 Peirce Smith | 3 Peirce Smith | 3 Peirce Smith |
| SLAG CLEANING | Electric Furnace + Cylindrical | (Slag Flotation) | Electric Furnace | 3 TSC Furnaces | Cylindrical | Electric Furnace | 4 Fuel fired Furnace |
| FIRE REFINING | 6 Anode Furnace + 2 Scrap Furnace | 3 Tilting Furnaces | 1 Anode Furnace | 2 Anode Furnaces | 2 Anode Furnace | 1 Rotary Anode Furnace + 2 Furnace Reverb | 3 Rotary Anode Furnace + 3 FR Furnaces |
| CASTING WHEEL TYPE | 3 Outokumpu Casting Wheels | 2 Outokumpu Casting Wheels | Outokumpu Casting Wheel | Twin Demag Casting Wheel | 1 Outokumpu Casting Wheel | Walker Casting Wheel | 2 Outokumpu Casting Wheels |

# TENIENTE CONVERTER TECHNOLOGY



# CODELCO TENIENTE TECHNOLOGY

- Teniente Converters operating since the 70´s
- At present there are 7 units in operation in Chilean Smelters
- Total smelting capacity of 4.8 MM tpy concentrates yielding 1.7 MM tpy copper

➢ **The Teniente Converter**

- Smelts concentrates and performs the initial Conversion slag-blow
- Yields 75% Cu white metal

➢ **The Teniente Slag Cleaning Furnace**

- Treats Teniente slags - usually of 5 to 7% Cu
- Yields matte and final discard slag

➢ Complementary devices improving operations

- Tuyere blocks for expediting tuyere hot-repairs

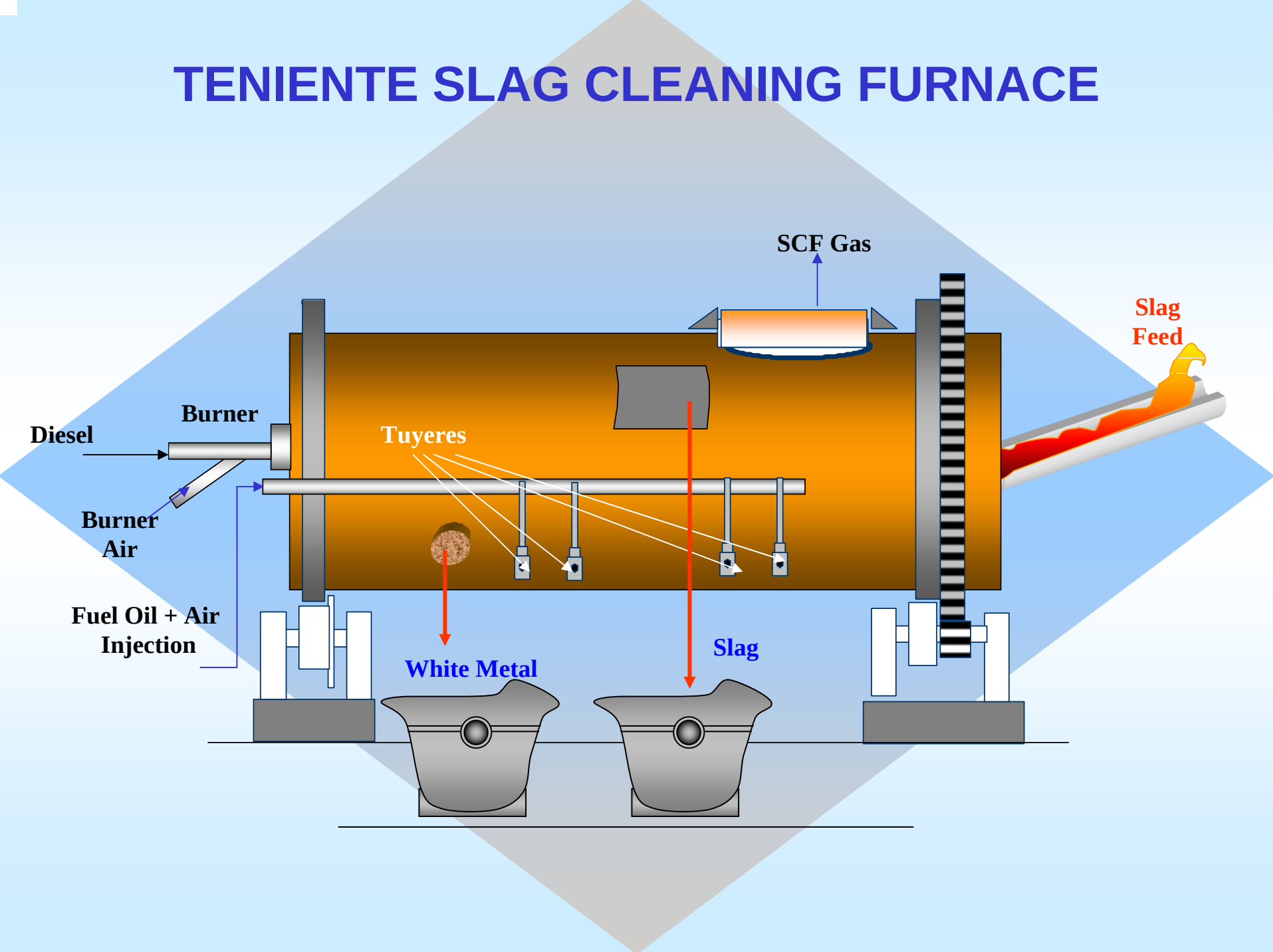
# TC Dry Concentrate Injection

- Bone-dry Concentrate Injection through tuyeres dense/ultra-dense phase pneumatic transport (*80 to 140 kg material conveyed per kg transport air*)
- Preceded by an efficient Dryer (rotary, fluid bed or steam), to produce bone-dry concentrate at 0.2% moisture
- Ultra Dense-phase injection has permitted up to 100% capacity increase of Teniente Reactor

# Teniente Converter Production Capacity in Chile

| COMPANY | SMELTER | CT TOTAL | DIMENSIONS L x D (m) | CONCENTRATE SMELTER CAPACITY | | | |
|---|---|---|---|---|---|---|---|
| | | | | DAILY | | | YEARLY |
| | | | | DESIGN | NOMINAL | | |
| | | | | TPD | TPD | TPH | TPY |
| CODELCO | Caletones | 2 | 22 x 5 | 2,600 | 2,300 | 98 | 1,600,000 |
| CODELCO | Chuquicamata | 1 | 22 x 5 | 2,500 | 2,200 | 100 | 748,000 |
| CODELCO | Potrerillos | 1 | 22 x 5 | 2,200 | 2,000 | 90 | 680,000 |
| CODELCO | Ventanas | 1 | 14 x 5 | - | 1,400 | 60 | 450,000 |
| ENAMI | Paipote FHVL | 1 | 14.9 x 3.8 | - | 1,050 | 65 | 357,000 |
| NORANDA | Alto Norte | 1 | 26.4 x 5.3 | - | 2,800 | 120 | 950,000 |
| Total | | 7 | | | 11,750 | 533 | 4,785,000 |

# TENIENTE SLAG CLEANING FURNACE



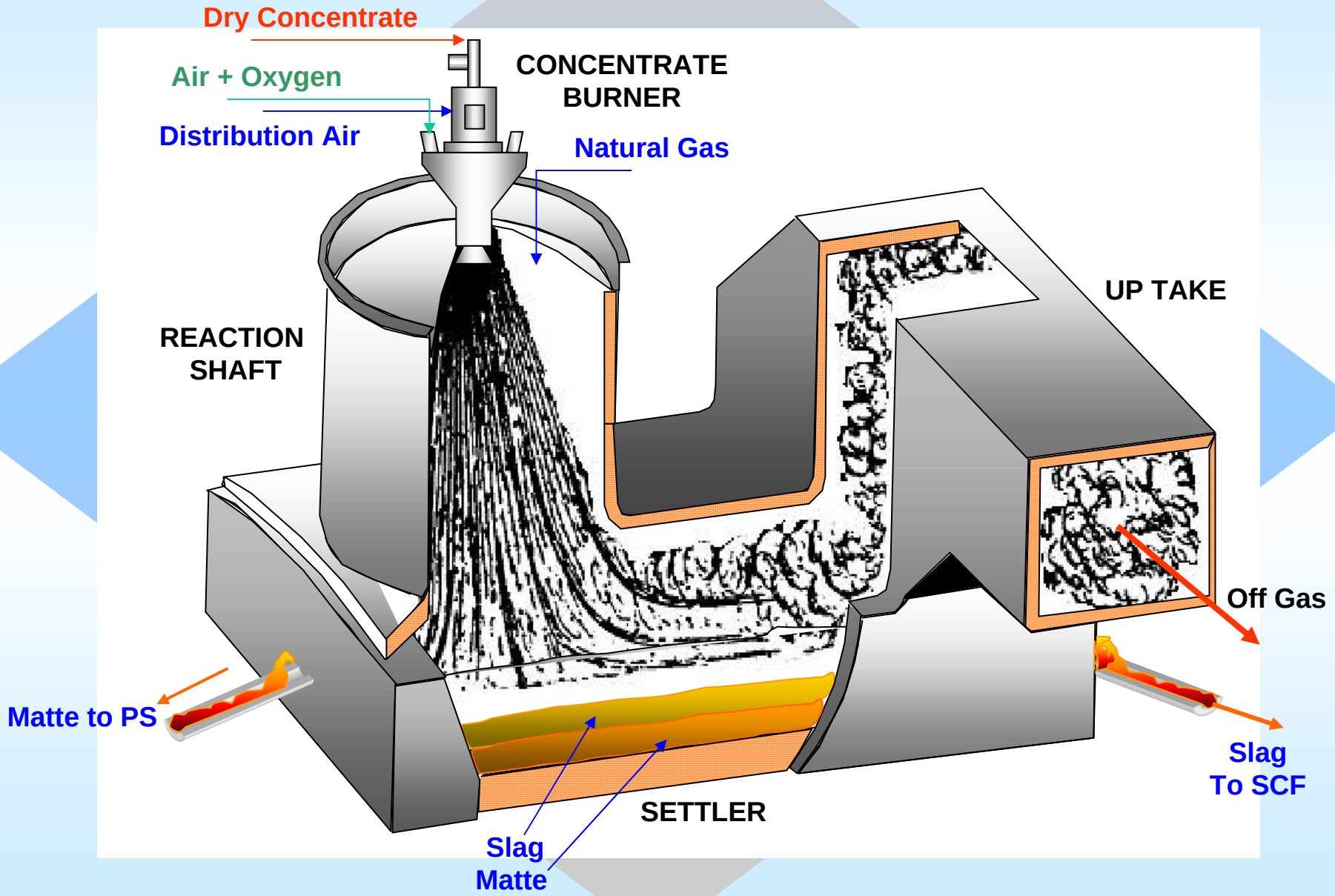
# TENIENTE SLAG CLEANING TECHNOLOGY

- Based on Oil or Coal injection through tuyeres to a Rotary Furnace
- Operating since the 80´s, first at Caletones Smelter
- At present there are 9 units in operation in Chilean Smelters
- Slag cleaning capacity 600 to 1,000 tpd slag per furnace

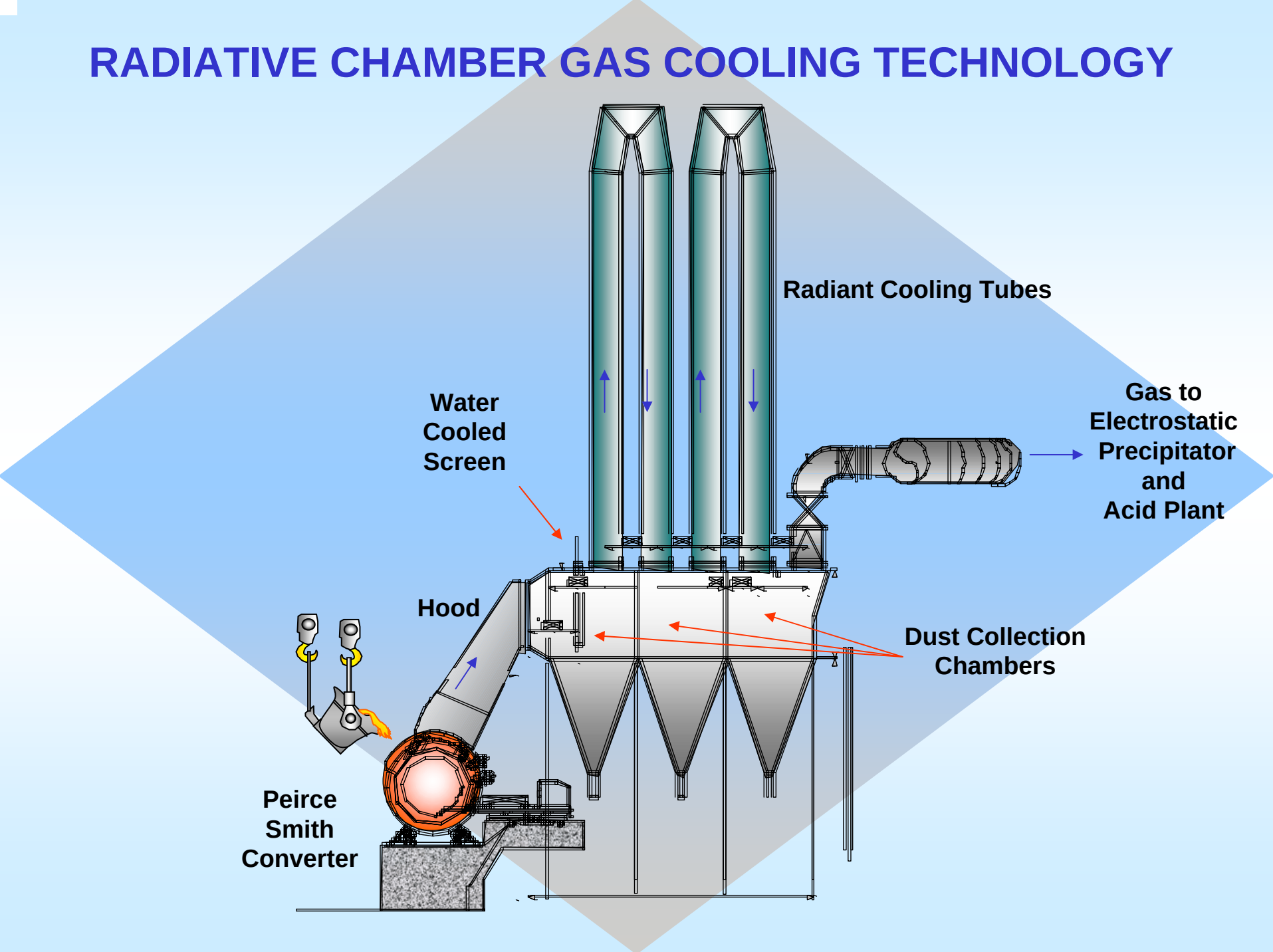
➢ **The Teniente Slag Cleaning Furnace**

- Magnetite reduction using fuel reductant, plus auxiliary burner, followed by matte settling period
- Treats molten slag from CT or Flash Furnace; converter slag can also be added, with limitations (high $Fe_3O_4$ needs strong reduction)
- Yields matte and final discard slag
- Final slag usually 0.8 to 1.0 %Cu
- Different feed and product discharge configuration
- Batch or Semi-continuous process (continuous under development)

# FLASH SMELTING FURNACE



# RADIATIVE CHAMBER GAS COOLING TECHNOLOGY



# Radiative Cooling of Metallurgical Gas

Pairs of exposed bare metal ducts - approx 1.2 m diameter x 17 m

Heat is definitively removed from the gas train.

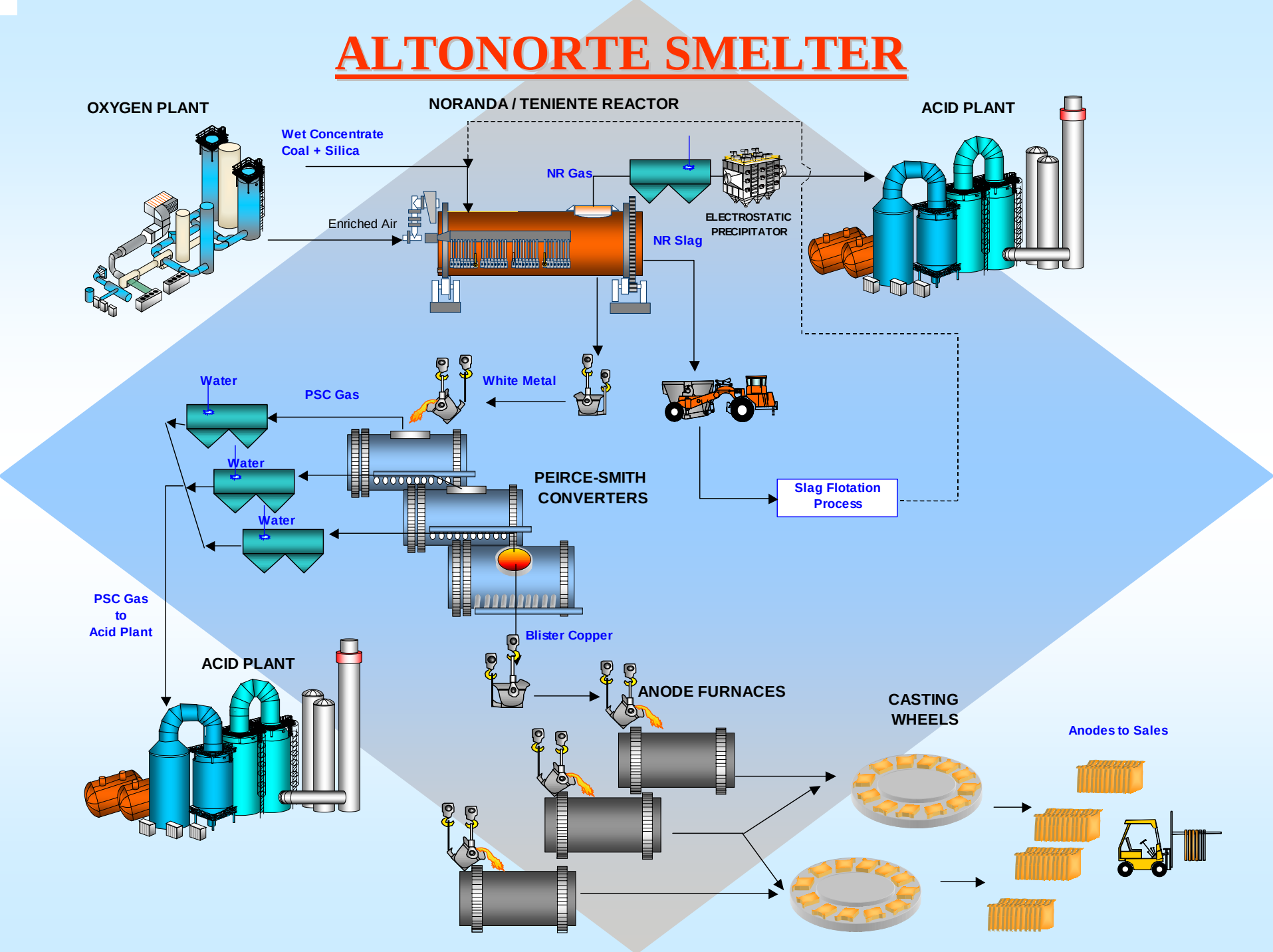
In some cases with smaller and multiple tube bundles for P-S Converters, with final forced air convection double tube section.

On occasions combined with final evaporative cooling (spray) for temperature adjustment.

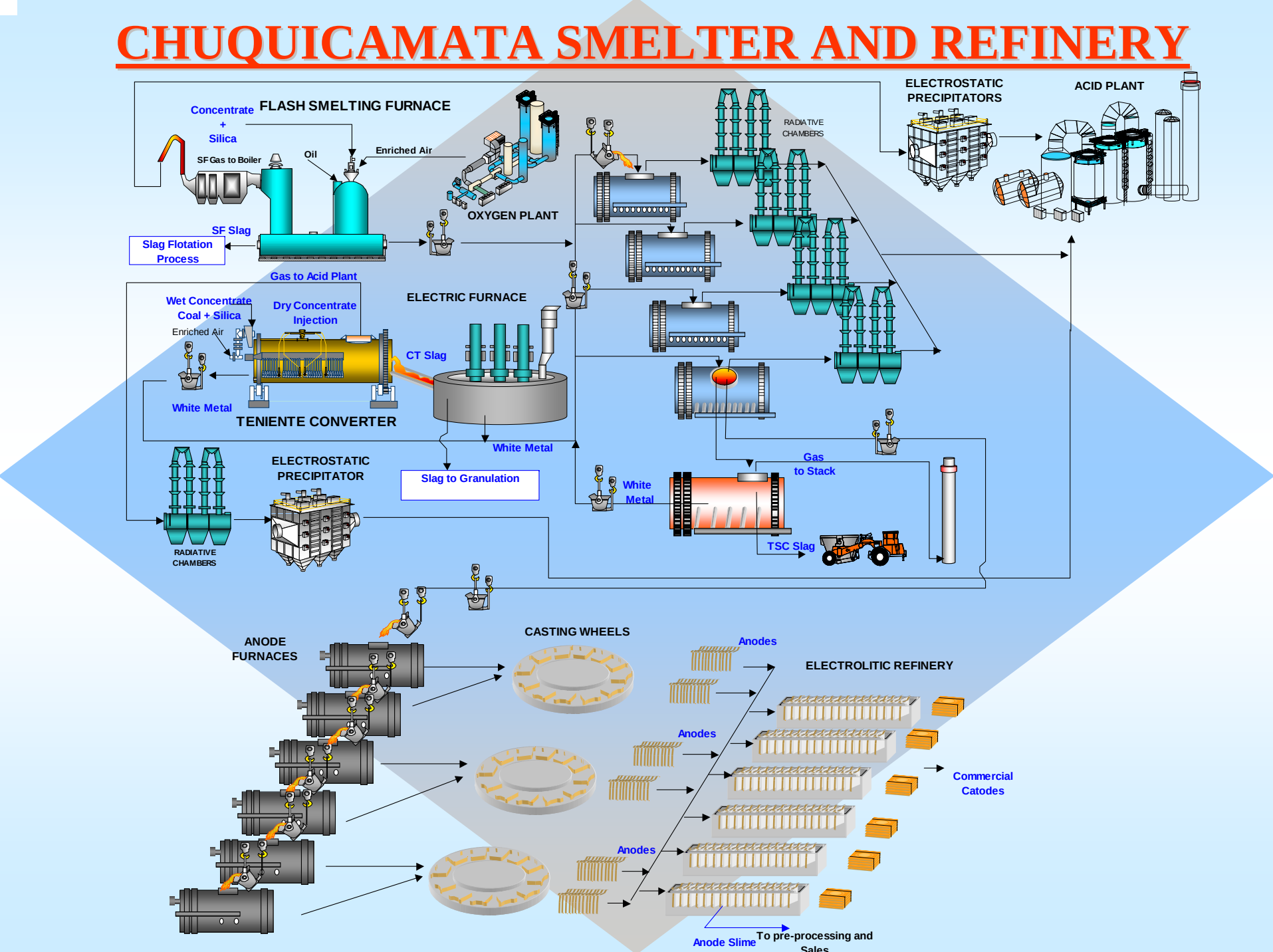
Successful installations at :

Chuquicamata, Caletones, Potrerillos, Paipote, La Caridad Smelter in Mexico, and presently at MSA Chagres Smelter.

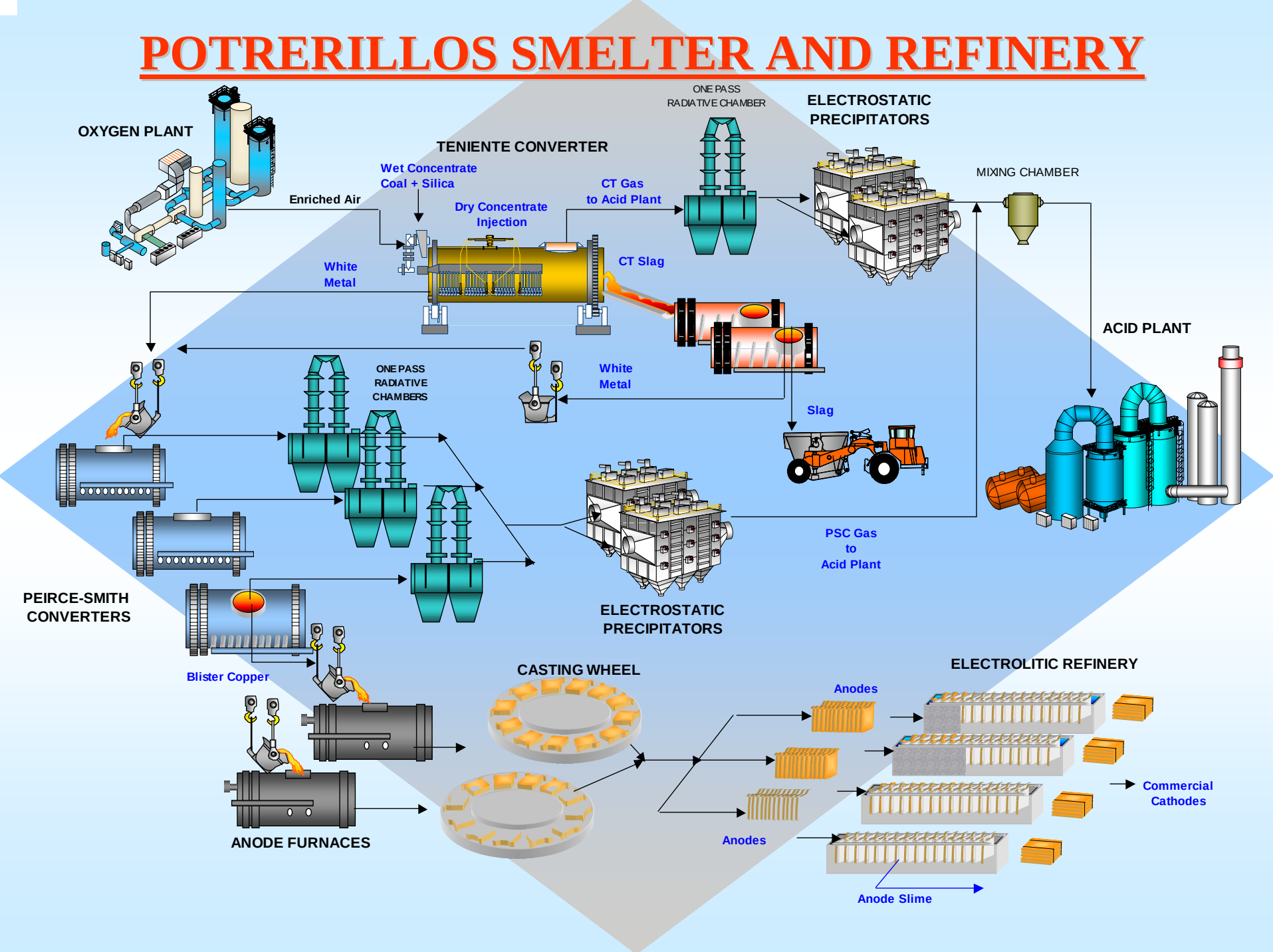
# ALTONORTE SMELTER



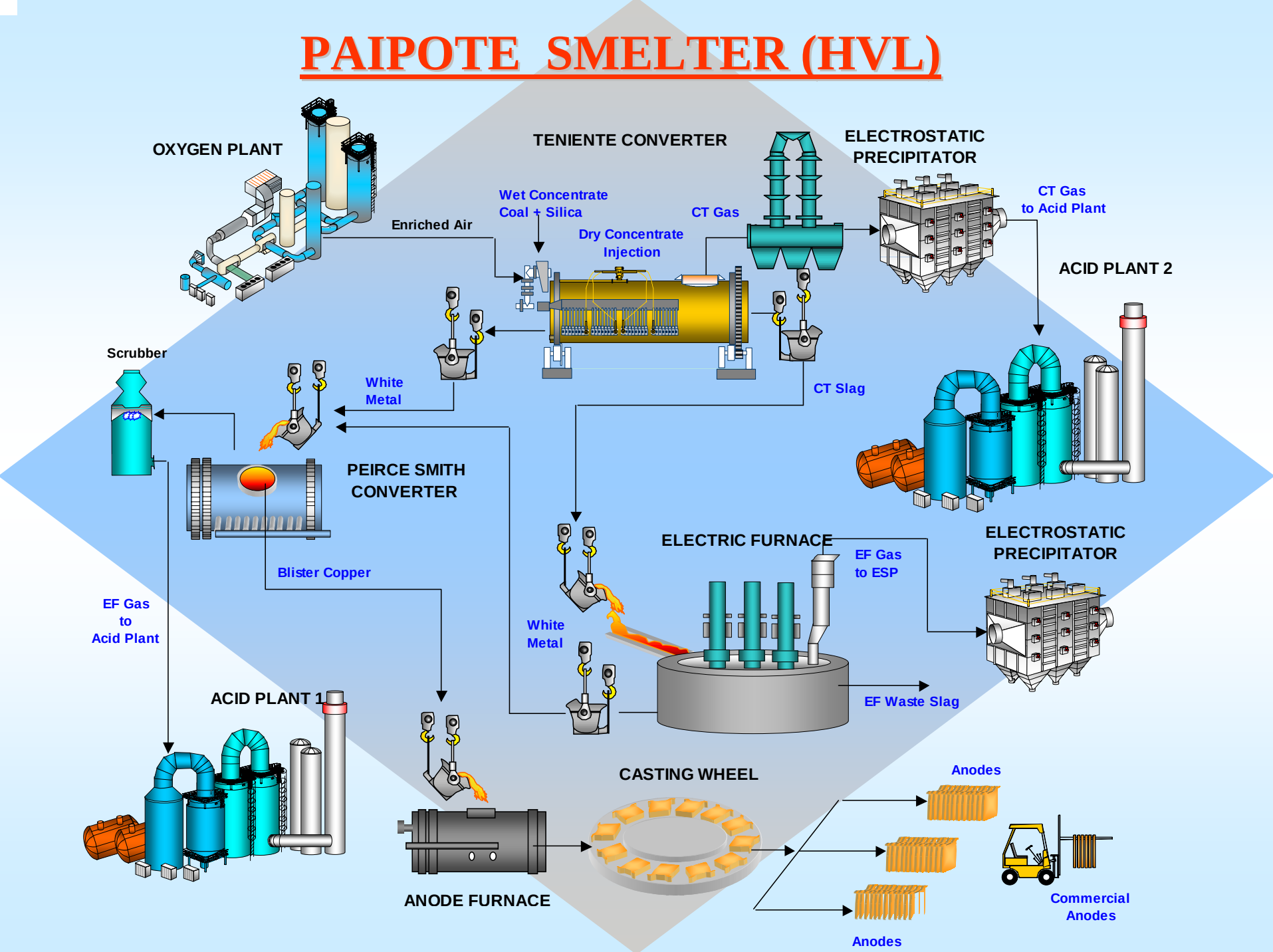
# CHUQUICAMATA SMELTER AND REFINERY



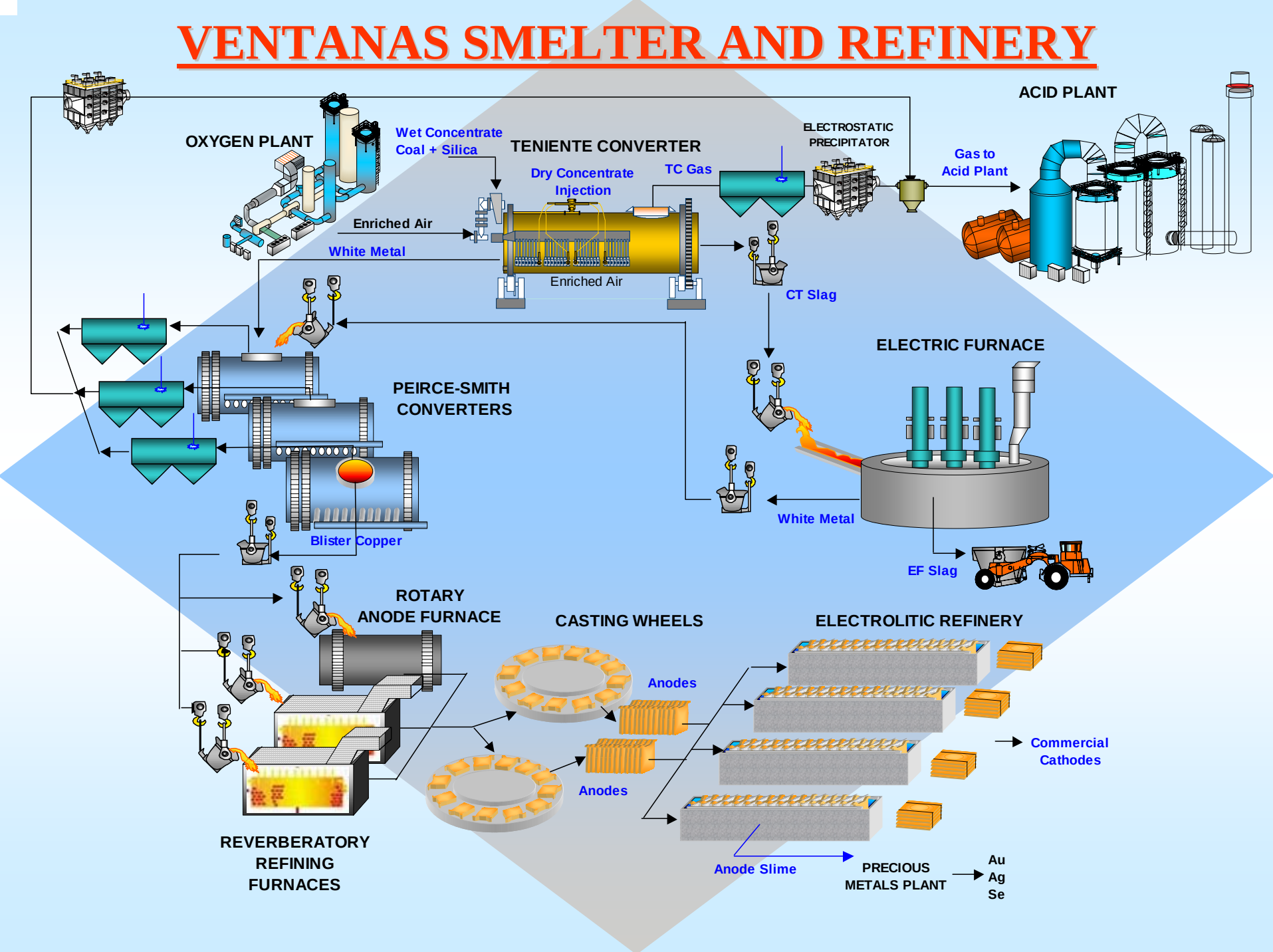
# POTRERILLOS SMELTER AND REFINERY



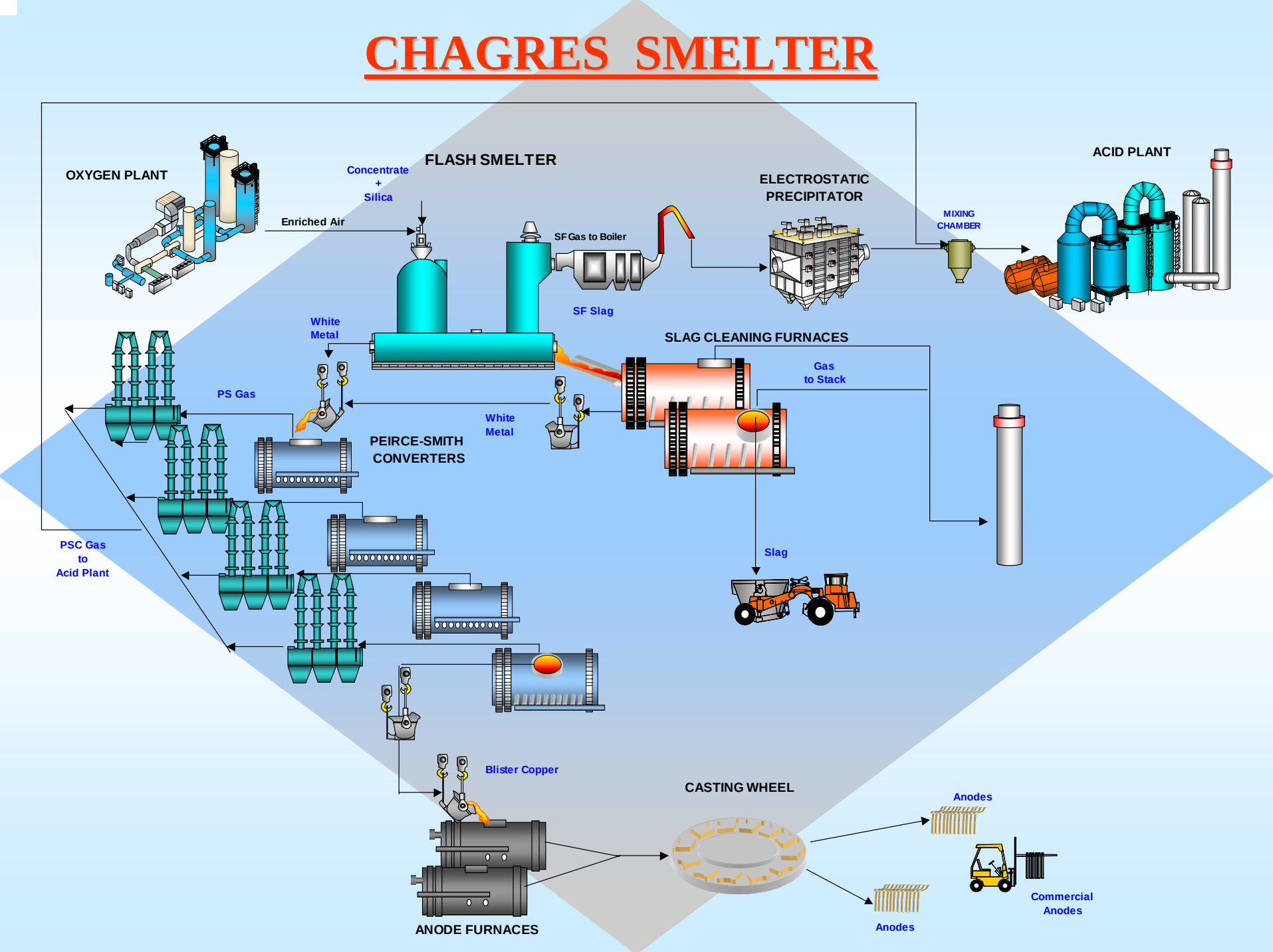
# PAIPOTE SMELTER (HVL)



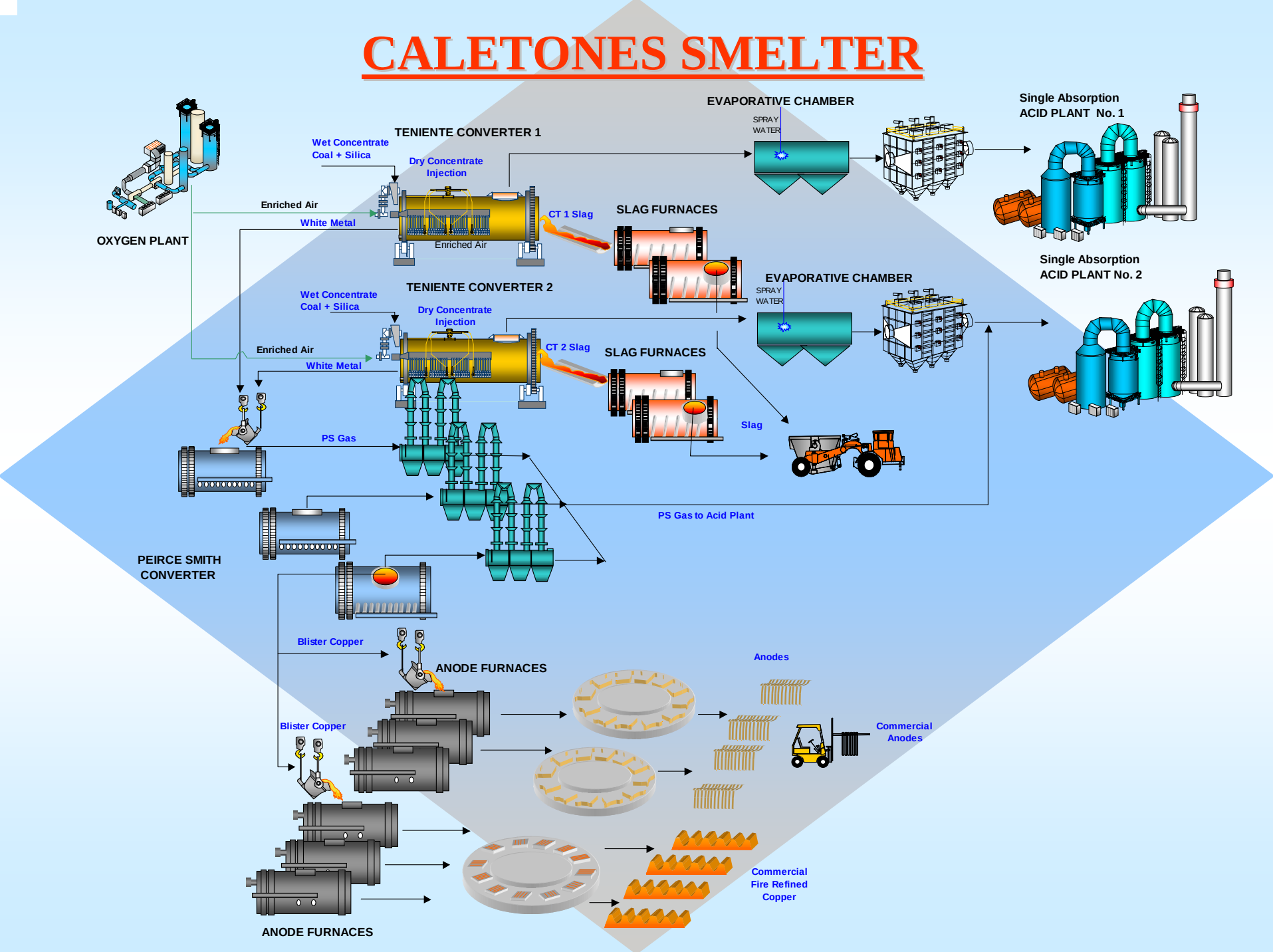
# VENTANAS SMELTER AND REFINERY



# CHAGRES SMELTER



# CALETONES SMELTER



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