QUESTIONS AND ANSWERS

DIANODIC II™

COOLING WATER TREATMENT

BETZ

BETZ DIANODIC II™ COOLING WATER TREATMENT

QUESTION:
What is Dianodic II?

ANSWER:
Betz Dianodic II is a new breakthrough in nonchromate cooling water treatment technology. It is a two component treatment program featuring a truly effective calcium phosphate inhibitor that permits higher phosphate concentrations necessary for proper mild steel corrosion protection.

The first component is the corrosion inhibitor—a blend of orthophosphate and polyphosphate for ferrous metal protection, phosphonate for calcium carbonate prevention and a copper corrosion inhibitor.

The second component is the calcium orthophosphate inhibitor/dispersant. This is what makes this program work, and in our opinion, forms the best non-chromate treatment available in the marketplace.

QUESTION:
What are the features and benefits of Dianodic II?

ANSWER:

FEATURES	BENEFITS
Environmentally acceptable	Allows compliance with majority of water quality standards (PO_4 was not added to EPA's Toxic Pollutants List)
No heavy metals	Avoids hazardous sludge disposal. Municipal heavy metal surcharges are eliminated, or operating costs of chrome removal are eliminated.
Corrosion results comparable to chromate zinc programs	Less tuberculation, minimum equipment maintenance, maximum exchanger life.
Provides a γ Fe_2O_3 passivating film	Greater stability and fast recovery from upsets without serious corrosion occurring
Positive deposition control	Better heat transfer, higher production, and decrease in turnaround frequency and downtime.
Compatible in wide range of waters	May allow higher cycles thus conserving water and overall costs.
Analytical methods available	Ease in testing for use concentrations of Betz 2020 and Betz 2040 separately.
Available on Point of Feed(R) Service	Betz maintains inventory control and provides tankage. Less paperwork, no drum handling.

QUESTION:
How does Dianodic II differ from conventional nonchromate programs?

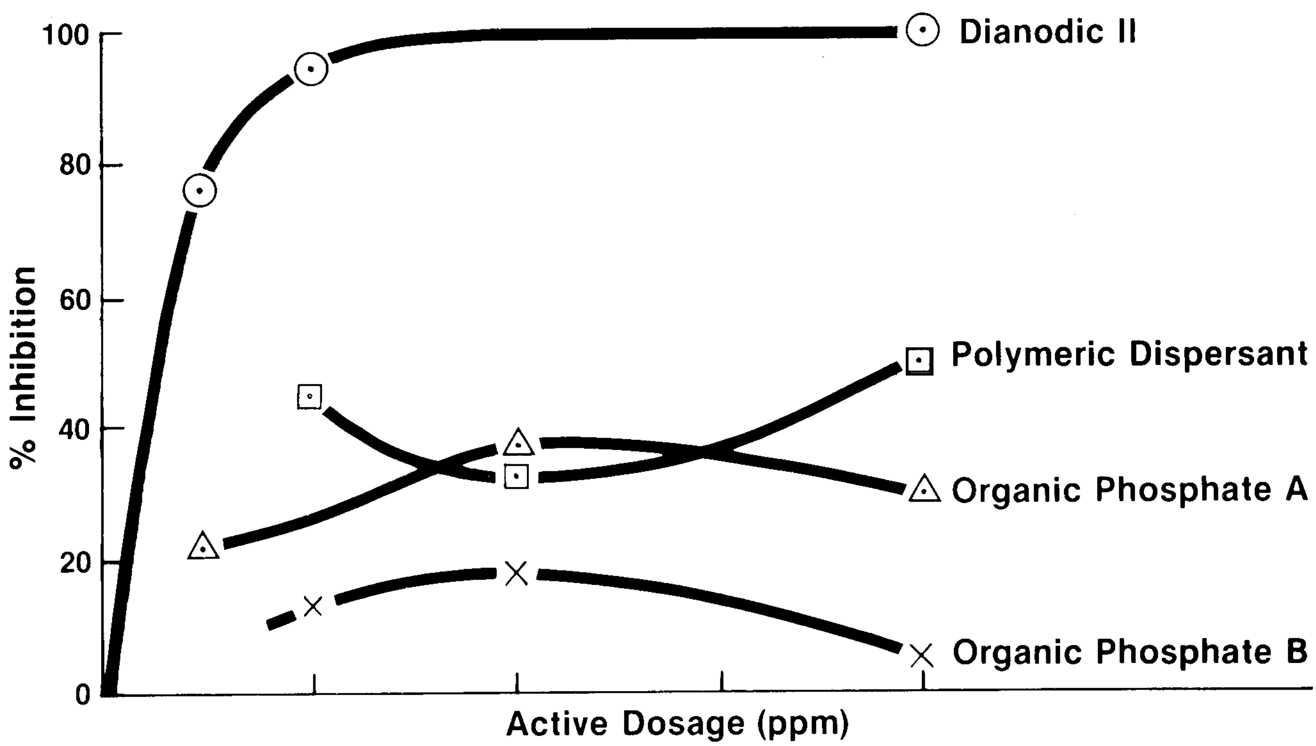
ANSWER:
The basic difference is in the orthophosphate levels that are carried. Conventional programs operated at a pH of 7 will typically have no more than 5-7 ppm orthophosphate. The new Dianodic II program will operate at control limits of from 10-17 ppm orthophosphate.

It is well established that higher levels of orthophosphate provide improved corrosion protection. However, until the advent of Betz 2020, the higher orthophosphate levels could not be achieved without precipitating calcium orthophosphate. The unique ability of Betz 2020 to control calcium orthophosphate allows improved protection without calcium phosphate fouling.

QUESTION:
Just how good is Betz 2020 in its ability to control calcium orthophosphate precipitation/deposition?

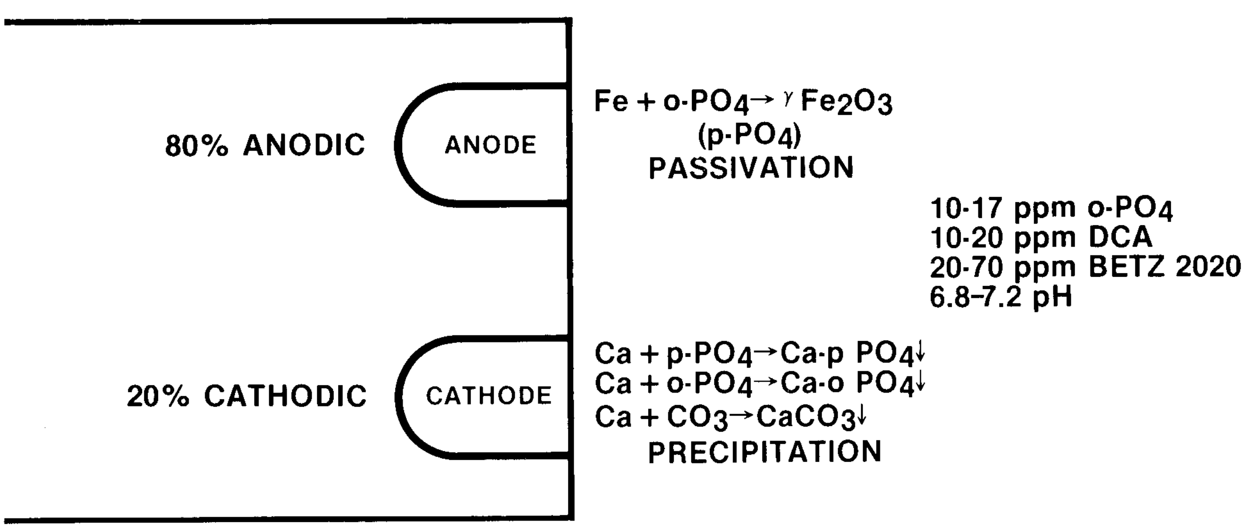
ANSWER:
You can get some indication by the orthophosphate levels carried in the Dianodic II program. To be more specific, in one controlled experiment at a calcium phosphate index of +2.2 (a very severe condition), Betz 2020 provided 96-98% inhibition of calcium phosphate precipitation at recommended use levels compared to 13-43% by standard dispersants commonly used with phosphate programs. (Refer to next page).

Calcium Phosphate Inhibition



BETZ DIANODIC II®

Patented 1979 Through the 1980's



Dianodic II is primarily dependent on the anodic inhibition reaction

MECHANISM

QUESTION:
What mechanism can explain how Dianodic II functions?

ANSWER:
Anodic and cathodic inhibitors control steel corrosion. The primary anodic inhibitor is orthophosphate. It acts, like chromate, to promote the formation of a passive iron oxide film (γ-Fe_2O_3) on the metal surface. In previous treatments the amount of orthophosphate that could be added was limited by excess precipitation of calcium orthophosphate which produced fouling. The addition of Betz 2020 to the treatment controls this precipitation and allows much higher levels of orthophosphate, and thus much more effective anodic inhibition. In addition to orthophosphate, polyphosphate, which also functions as an anodic inhibitor, is included in the Dianodic II Program. Both phosphates require oxygen to be effective.

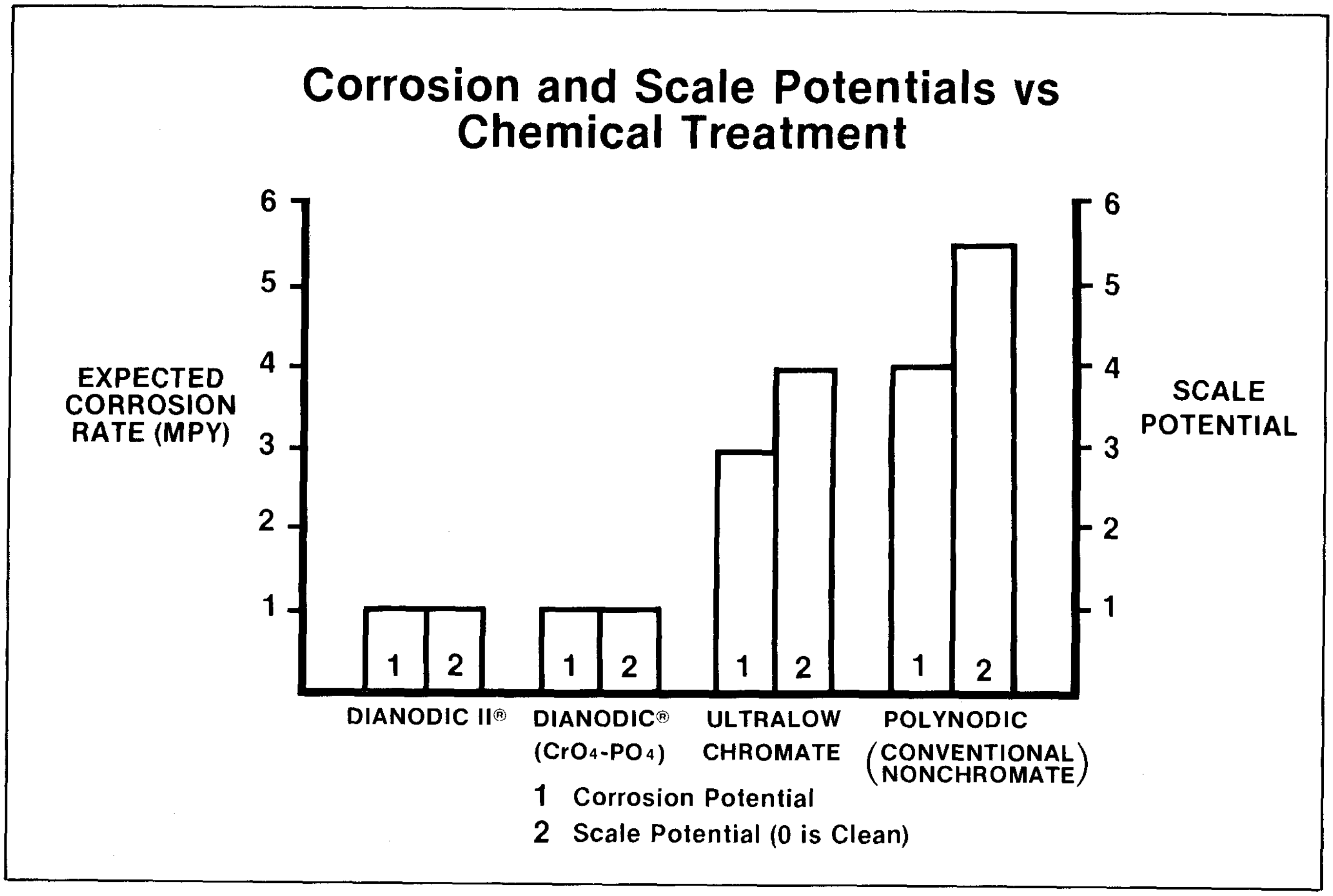
Ortho and polyphosphate also act as cathodic inhibitors, and thus the cathodic inhibition in Dianodic II treatment is provided by them and by the natural alkalinity (carbonate) in the water. All three form calcium salts which precipitate locally at high pH cathodic sites, and thus stifle the cathodic reaction. The key to the success of the cathodic inhibition in Dianodic II is that the calcium salt precipitation is *controlled* and thus fouling is prevented. The Betz 2020 controls the calcium orthophosphate precipitation and a phosphonate controls the calcium carbonate precipitation. Excess calcium polyphosphate precipitation is not a problem at normal treatment levels.

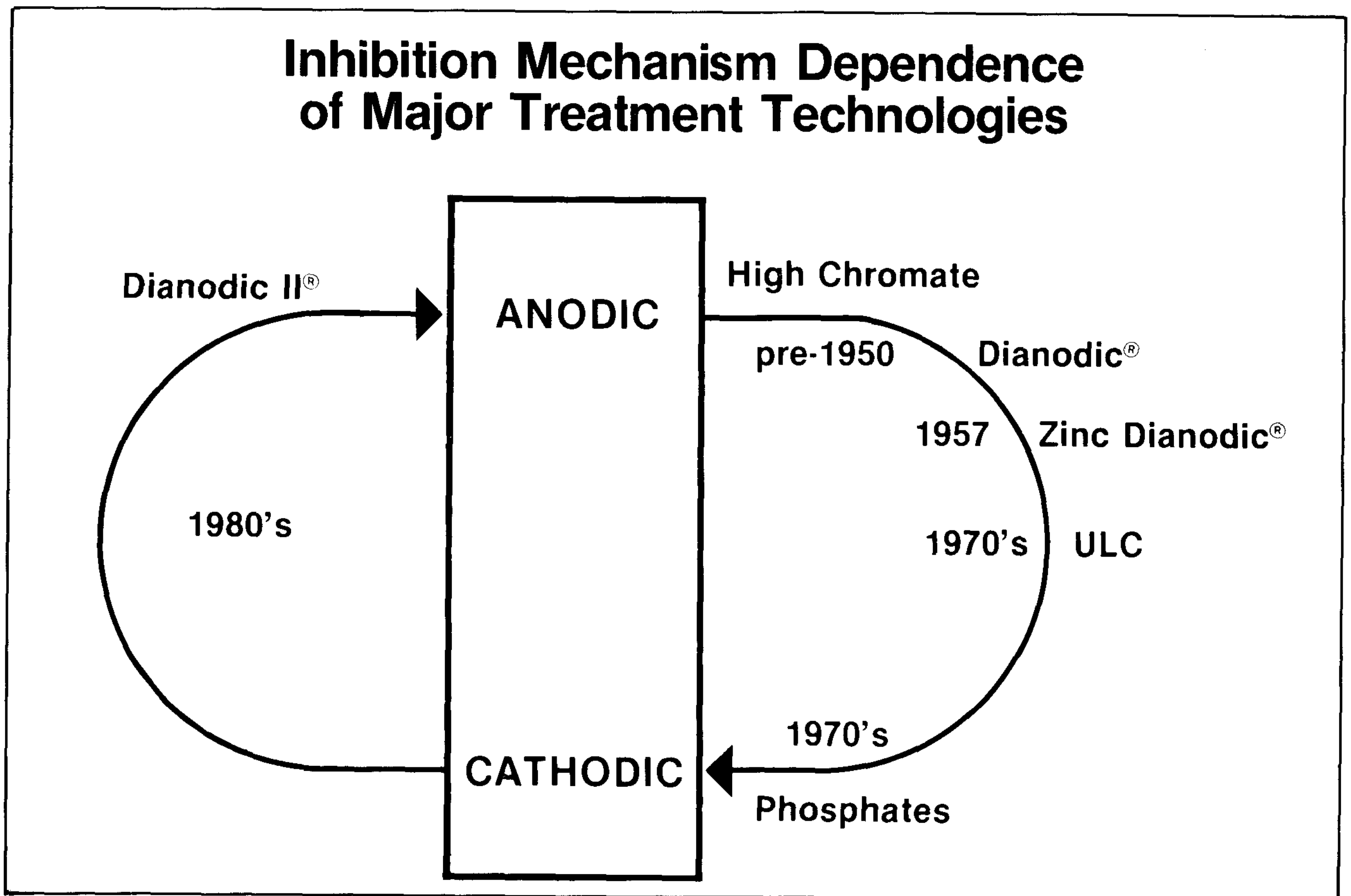
The advantage of combining anodic and cathodic inhibitors is well established. The anodic passive film protects the bulk of the metal surface; whereas the controlled cathodic precipitation prevents pitting at any local sites which have not been passivated. The addition of a cathodic inhibitor is particularly important in cooling systems because the overall corrosion rate is controlled by the rate of the cathodic reaction (reduction of oxygen), and thus rapid localized corrosion can occur at metal sites which are not passivated.

QUESTION:
What is so important about a γ Fe_2O_3 film? Why is it so much better than the inhibitor film formed from previous phosphate based treatments?

ANSWER:
The γ Fe_2O_3 film is important because it is a true passive film for steel. It is the same protective film that is formed on mild steel in chromate inhibited water and that is naturally present on stainless steel. It is very protective and adherent, and will tend to be reformed if it is removed by an upset.

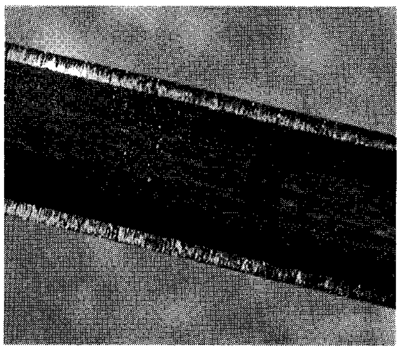
Previous phosphate based treatments did not contain enough orthophosphate to effectively form this γ Fe_2O_3 film. These treatments rely on barrier-type films for the bulk of their protection. The precipitated barrier films are not as adherent and protective, and do not reform as readily after system upsets. Excessive precipitation can cause fouling in high temperature exchangers or with less than excellent control.


Corrosion and Scale Potentials vs
Chemical Treatment
EXPECTED CORROSION RATE (MPY)
SCALE POTENTIAL
6
5
4
3
2
1
DIANODIC II®
DIANODIC® (CrO_4-PO_4)
ULTRALOW CHROMATE
POLYNODIC (CONVENTIONAL NONCHROMATE)
1 Corrosion Potential
2 Scale Potential (0 is Clean)

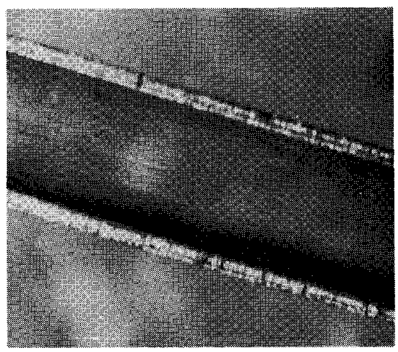

Inhibition Mechanism Dependence
of Major Treatment Technologies
ANODIC
CATHODIC
Dianodic II®
1980's
High Chromate
pre-1950
Dianodic®
1957
Zinc Dianodic®
1970's
ULC
1970's
Phosphates

Dianodic II Vs. Conventional Chromate-Zinc and Nonchromate Treatment Results

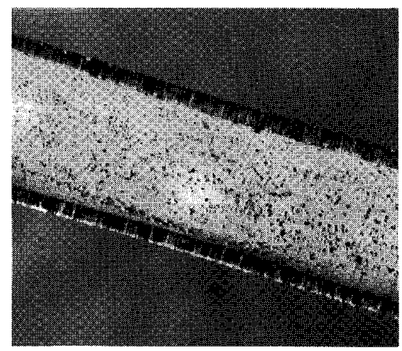
Heat Exchanger Tube Sections (No Magnification)



Conventional Chromate
Zinc-organic phosphate
treatment

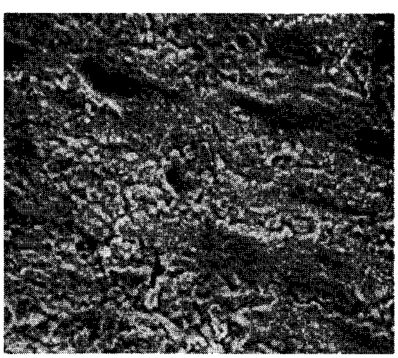


Dianodic II
Treatment

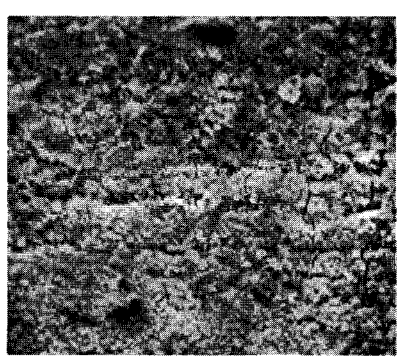


Conventional
nonchromate
treatments

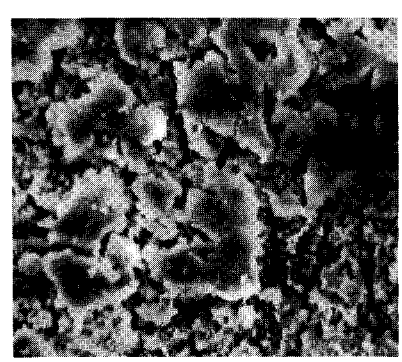
Scanning Electron Microscope Photographs of tube Surfaces (300X Magnification)



Conventional Chromate
Zinc-organic phosphate
treatment



Dianodic II
Treatment



Conventional
nonchromate
treatments

ENVIRONMENTAL CONSIDERATIONS

QUESTION:
Are there any environmental considerations if we use Dianodic II?

ANSWER:
Dianodic II is a relatively non-toxic, non-heavy metal treatment program. The components of Dianodic II are used in numerous Betz products and at its normal feedrate of 100 ppm is practically non-toxic to mammals or fish. For Betz 2020, the LC_{50}* on *D. magna* is greater than 500 mg/1. At the recommended feedrate of 20-60 ppm, its COD contribution is only 5-15 ppm, TOC is 5 ppm and BOD is less than 4 ppm.

QUESTION:
Isn't the EPA proposing to add phosphorus to its list of conventional pollutants?

ANSWER:
The EPA has made a final ruling to withdraw its contention that phosphorous be listed as a conventional pollutant. This is recorded in the Federal Register, volume 44, number 147, page 44501, dated Monday, July 30, 1979.

QUESTION:
Won't higher phosphate levels result in excessive biological growths?

*LC_{50} is lethal concentration where 50% of the species survive.

ANSWER:
No. Typically, microbiological growths in cooling systems are limited by the available carbon, *not* phosphorus. There is sufficient phosphorus for biological growths with less than 0.15 ppm orthophosphate in a water. Higher phosphates will not lead to additional biological growth since there is not enough carbon to support an increase in biomass.

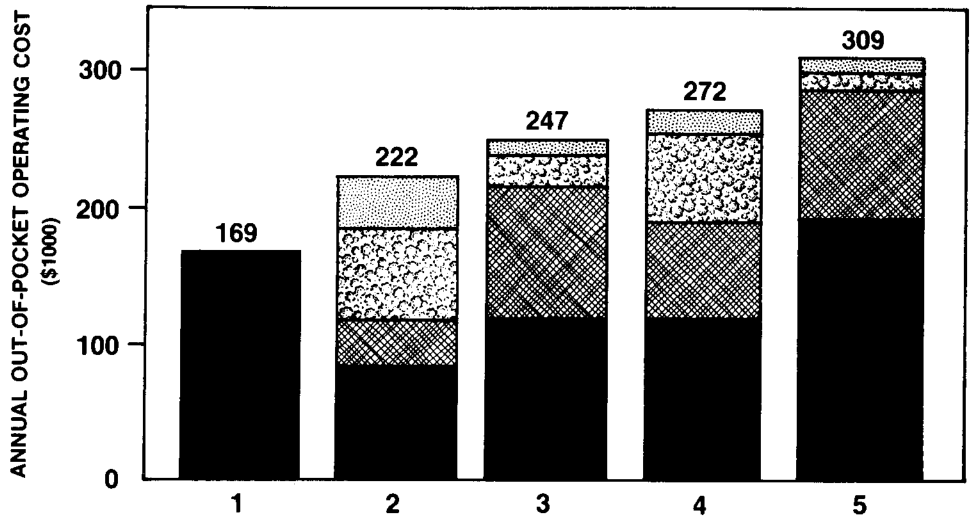
ALTERNATIVE METHODS OF REDUCING CHROMATE DISCHARGE

BASIS:

Circulation Rate	=	90,000 gpm
Temperature Drop	=	17F
Cycles	=	5
Evaporation	=	1530 gpm
Total Blowdown	=	390 gpm
Blowdown to Sewer	=	300 gpm
Chromate	=	20 ppm
Zinc	=	3 ppm
Phosphate	=	5 ppm

Estimated capital and operating costs for heavy metal removal or recycle alternatives are presented on page 7.

ANNUAL OPERATING COSTS REQUIRED TO MEET ENVIRONMENTAL REGULATIONS*

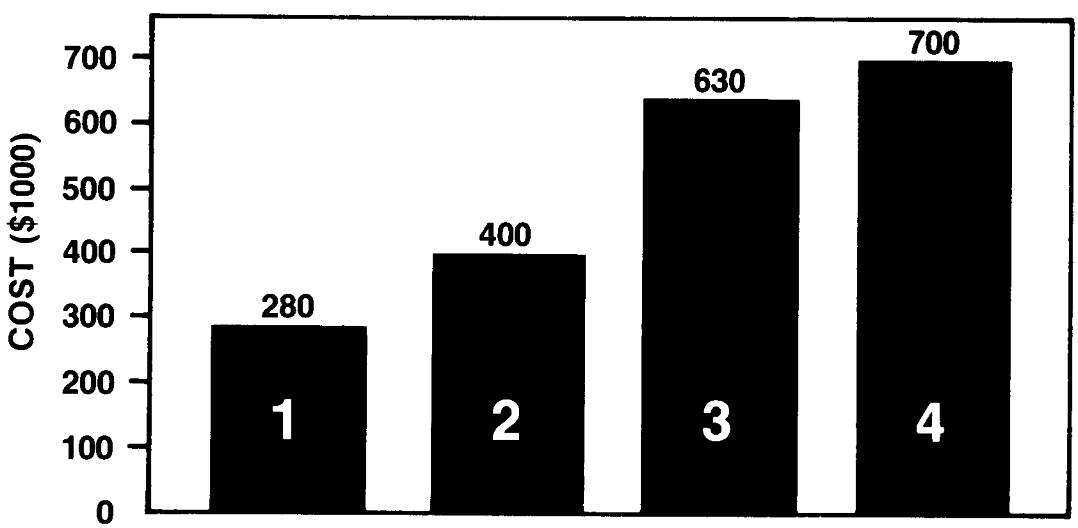


KEY:
1 = DIANODIC II®
2 = ION EXCHANGE
3 = CHEMICAL REDUCTION
4 = ELECTROCHEMICAL REDUCTION
5 = ZERO BLOWDOWN (Sidestream Softening)

MAINTENANCE MATERIALS AND LABOR
OPERATING LABOR
MATERIALS USED TO OPERATE EQUIPMENT
WATER TREATMENT CHEMICALS

*Sludge And Regenerant Chemical Disposal Costs Not Included

INSTALLED CAPITAL COST FOR CHROMATE REMOVAL/RECOVERY EQUIPMENT



KEY:
1 = COLD LIME SIDESTREAM SOFTENING
2 = CHEMICAL REDUCTION
3 = ELECTROCHEMICAL
4 = ION EXCHANGE

Note: Sludge Dewatering Equipment Not Included.