THE ECONOMICS OF ANION RESIN SELECTION IN TWO BED DEMINERALIZERS (TYPE 2 AND TYPE 1 GELS)

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Time limits us to a brief discussion, so I have focussed this discourse on matters with the most potential benefit. We will use sample problems to demonstrate economic analysis as an approach to resin use and selection. Additional material will be available upon request on the following items:

General Resin Properties
A comparison of the relative merits of the different types of ion exchange resins.

Information on regeneration methods
* HCL vs H2S04 for cation resins
* Cocurrent vs countercurrent regeneration

Various Ion Exchange Process such as:
* Two bed demineralizers
* Multiple bed demineralizers with and without degassifiers
* Softeners
* Dealkalizers
* Desilicizers etc.

This article discusses the economics of strongly basic anion resin selection and regeneration levels in cocurrent regenerated anion exchange vessels (mixed beds are not included). This means we will be comparing Type 1 strongly basic resins against Type 2's. **Table 1** shows the relative benefits of each. **Figures 1 & 2** compares operating capacity and silica leakages.

BACKGROUND:
The main reason I have chosen this topic is that it reflects common practice and is responsive to current regional economics.

* Anion resins are less stable, cost more to replace and have to be replaced more often than cation resins. Therefore, anion resins cost several times as much to own and operate per gallon of produced deionized water than cation resins.

* Essentially all demineralizing equipment is operated with a strong base anion resin in a single vessel as part of the "workhorse section" of the demineralizing train. The anion vessel is mostly regenerated cocurrently. Most operating anion vessels were installed when economic factors for selecting types of anion resins and regeneration levels were quite different from today.

Sodium hydroxide prices were 50% of today's prices. Anion resin prices were 30 - 70% less than today's prices.

* Sodium hydroxide is in short supply, and in some cases on allocation with prices that are continuing to escalate.

* Sulfuric acid is produced locally and is extremely inexpensive here.

The fact is that new Type 2 resins give much higher operating capacities with good silica leakages and yet, the majority of anion vessels in service today filled with strongly basic anion resins are using Type 1's. Most of these vessels are regenerated at 6 pounds of sodium hydroxide per cubic foot.

It is also well known that Type 2 resins change rapidly with age. After one year in service as much as 50% of their strong base capacity (for silica & CO_2) can become changed to weakly basic. This weakly basic capacity is limited to reacting only with strong acid anions like sulfate and chlorides. This is not all bad when you consider that they operate at almost 100% regeneration efficiency and free up the much less efficient strong base sites to work on the weak acids. Depending on the regeneration level and water analysis, these changes can be beneficial. We can show that at low regenerant levels on high chloride waters operating capacity increases with age for a Type 2 resin. On the other hand the loss in operating capacity at high regeneration levels treating a water containing 100% silica is proportional to the loss in strongly basic capacity.

A laboratory test result showing the composition of the resin does not tell anything about its operating capacity. Likewise, the change in strong base to weak base capacity does not predict changes in operating capacity. In the last three years ResinTech has developed the technology to predict, to a fair degree of accuracy, the changing operating capacity for specific cases as a resin ages. This technology can be used to simulate ageing or to interpret laboratory test results to generate performance curves for older resins so that they can be compared with new resins. We can also combine these to developed "what if" scenarios on resin replacement. We can change replacement frequencies and compare caustic savings with increased resin replacement costs also.

When todays operating systems were built, the OEM'S did not have the capability to accurately predict a change in operating capacity over time for specific cases. Instead, Type 1 or Type 2, strongly basic resins were selected by rote, based on a percentage of weak acids in the water. The selection criteria varied from as low as 25 to as high as 50 percent or more weak acids. The Type 1's were used when weak acids were above the selection point.

An economic comparison of Type 1 vs Type 2 resins with todays simulated performance technology will show that Type 2 resins would have been a better economic choice in many of these cases and/or that lower caustic regeneration levels of the Type 1 resins would have provided better economics.

There is a sufficient data that has been collected for the various types of resins to allow a prediction of the loss of total and salt splitting capacity for the Type 1 and Type 2 anion resins. ResinTech has correlated these losses against several environmental factors including, the presence or lack of oxygen in the water, the type of functional group, the polymer, the regeneration level, the exchanging ions, the effective operating temperature of the environment in which the resin is used and the time in service. Much of this data is summarized and discussed in two earlier papers by Gottlieb; "Economic Considerations in the Selection of Ion Exchange Resins" and "Ion Exchange Resins Selection and Performance Projections with a Personal Computer".

The following examples will show approach to resin selection and replacement frequencies that uses economics. To do this requires an estimate of future performance.

CASE #1 SELECTION OF RESINS

Table 2A & 2B is a comprehensive data sheet which describes the operating data, chemical costs and the water analysis for an operating demineralizer which has a Type 1 porous gel anion resin. The water analysis shows that the weak acids are just under thirty five percent (bicarbonates plus silica). The data sheet shows that the resin is regenerated at six pounds of sodium hydroxide at 4% at 120 Deg. F.

When it is new, a Type 1 porous resin will produce almost 16 kilograins of capacity per cubic foot in this installation. This calculates out to 7.1 hrs. between regenerations based on the flow rate data. Type 1 porous resins have good chemical and thermal stability. Under operating conditions like this and in the absence of organic fouling, only a slight drop in operating capacity is expected due to age. At the end of 4 yrs the run length will still be about 6.7 hrs.

In comparison, a Type 2 gel anion resin such as ResinTech SBG2 would give 21.8 hrs between regenerations. This represents an increased initial operating efficiency of 38 %. In other words the initial caustic consumption would decrease by 38 %! At the end of 4 yrs the Type 2 resin is still outperforming the Type 1 by 15%.

Averaging the performances over the four year period the Type 2 gives 18% more water per dollar spent on caustic. Other savings are also provided such as neutralization cost.

Figure 3 is a graph showing the projected operating capacities of the two types of resins in this particular system during a four year period. These projections are for operating capacities in ideal operating environments. Silica leakages and organic fouling impacts can be looked at individually.

Silica leakage - varies directly with regenerant temperature and inversely with regenerant efficiency. A Type 2 resin is regenerated at a lower temperature and is more efficient than a Type 1 resin. Therefore at equal regeneration levels the Type 2 resin will always give somewhat higher silica leakages. However both resins give low silica leakages. As the resins age and lose operating capacity the regeneration efficiency drops off and therefore the silica leakage drops by as much as 70% or more. Since a Type 2 resin ages more quickly, its silica leakage improves and approaches the Type 1. Reducing silica leakage is often clouded by organic fouling whose symptoms include increased silica leakages. Since the Type 2 is more resistant, it tends to do better.

Organic fouling - produces longer rinses, reduces operating capacity and increases silica leakage. The importance of fouling varies with each individual case. Generally when the T.O.C to T.D.S. exceeds 5% it becomes important. However there are no reliable methods for predicting fouling effects except for historical records. Many organics that show up in the T.O.C. tests have little or no detrimental effect on resins while others are deadly poisons to resins. For example ion exchange is used to process and purify concentrated sugar, acetic acid and formaldehyde solutions . These products would all show up on a T.O.C. test yet have no effect on the resin. On the other hand a few ppm of tannins or aromatic acids which contain nitrate, chlorides or carboxylic groups would quickly poison (foul) the resins.

Type 2 anion resins are much better at resisting organic fouling than their Type 1 counterparts. In waters known to have an organic fouling potential, if the economic projections of the two resins is close, organic fouling considerations would sway the decision towards selecting the Type 2.

The design of this plant called for an average of one million gallons a year to be processed through each cubic foot of anion resin. The cost of chemicals for regeneration and waste neutralization are shown in **Table 2**. Based on these and the projected changing operating capacities, we have estimated the average annual regeneration cost per cubic foot, over a 4 year period. It will be about $1183 per cubic foot per year for the Type 1 resin but, only $1,005 per cubic foot per year for a Type 2 resin. This represents a savings of $178 per cubic foot each year in caustic costs. Waste neutralization represents an additional savings between the two resins by selecting a Type 2 of $51 per cubic foot. The Type 1 resin is considered to have a useful life of 6 years. The Type 2 resin is generally replaced in 4 to 5 years, primarily due to the development of long rinses. Therefore the replacement cost of the Type 1 is less.

By switching to a Type 2 anion resin in this installation compared with a Type 1 the savings in caustic on an annual basis exceed the cost of the resin itself. This information is summarized in **Table 3**.

This particular projection shows a case of moderate regenerant level with a moderate to low content of weak acid ions in the water and the Type 2 is clearly superior. Higher regenerant levels and higher levels of weak acid ions reduce the advantage of the Type 2. Depending on the nature of the water and the regenerant level used, the Type 2 is not always the resin of choice.

When effluent requirements demand low silica levels and the influent water contains high levels of weak acid ions the economics may favor the Type 1 resin. Other factors to be considered in such cases are:

1. Extended regeneration time at lower regenerant levels, exchanges increased regenerant contact time for less caustic to achieve the same low leakage rate. It is possible to save as much as one-third or more on caustic levels and still achieve the same low silica using this method.

2. Counter current regeneration - In such situations, Type 2 or Type 1 resins can be used. Before this approach is considered a complete process analysis must be undertaken to insure success. For example the neutralization of silica laden caustic in the upper portions of the bed by bicarbonate and bisulfates can cause silica precipitation. In order to avoid this, certain minimum level of caustic regenerant may be required. After this level has been determined, then the process of selecting between the Type 1 and the Type 2 is undertaken.

3. Degassifiers are an easy way to reduce caustic consumption. For example, in this case, inserting a degasifier between the cation and anion vessels would reduce the anion loading by 35%. This would reduce caustic consumption by the same percentage. Since the water entering the anion vessel now has a lower ratio of weak acid ions, the situation is more favorable for a Type 2 resin which could provide an additional 20 - 25 savings in caustic.

The net result of using a degasifier and switching to a Type 2 resin in this installation would be a reduction in caustic consumption of about 50%.

There are several other kinds of resins that could be mentioned in this discussion, but time does not permit a full analysis of every possible case.

CASE #2 REPLACEMENT FREQUENCIES

Figure 4 shows a projection for a Type 2 resin annual regeneration costs for operation on a high chloride water. The upper curve shows costs from 4 to 8 years. The difference between the two lines is the annual savings in regenerant costs for resins replaced on a 4 year schedule. The cumulative savings shows that the savings are much greater than the costs of the resins. **Figure 5** shows the same information as **Figure 4** but for a 2 year replacement schedule. Since the caustic savings in **Figure 4** are less than the resin costs it does not make economic sense to replace the resin this quickly. The dotted lines show how the performance might be if organic fouling were present.

Figure 6 shows the difference in annual regeneration costs between a Type 1 and a Type 2 resin. Obviously, the Type 2 resin was the better choice.

TABLE 1

STRONGLY BASIC ANION RESINS

FEATURES

- COMPLETE ANION REMOVAL INCLUDING: SILICA AND CO2
- LOWER INITIAL COST
- VARIABLE EFFICIENCY
- VARIABLE QUALITY
- EXCELLENT KINETICS
- SHORTER RINSES

DRAW BACKS

- LESS ORGANIC FOULING RESISTANCE
- LIMITED LIFE
- THERMODYNAMICALLY UNSTABLE
- EFFICIENCY VS. QUALITY

TYPE 1 VS. TYPE 2

TYPE 1

- BETTER THERMAL STABILITY
- BETTER CHEMICAL STABILITY
- LONGER LIFE POTENTIAL
- CAN BE REGENERATED AT HIGHER TEMPS. (SILICA)
- SHORTER RINSES

TYPE 2

- HIGHER OPERATING CAPACITY
- HIGHER REGEN EFFICIENCY
- IMPROVED ORGANIC FOULING RESISTANCE

FIGURE 1

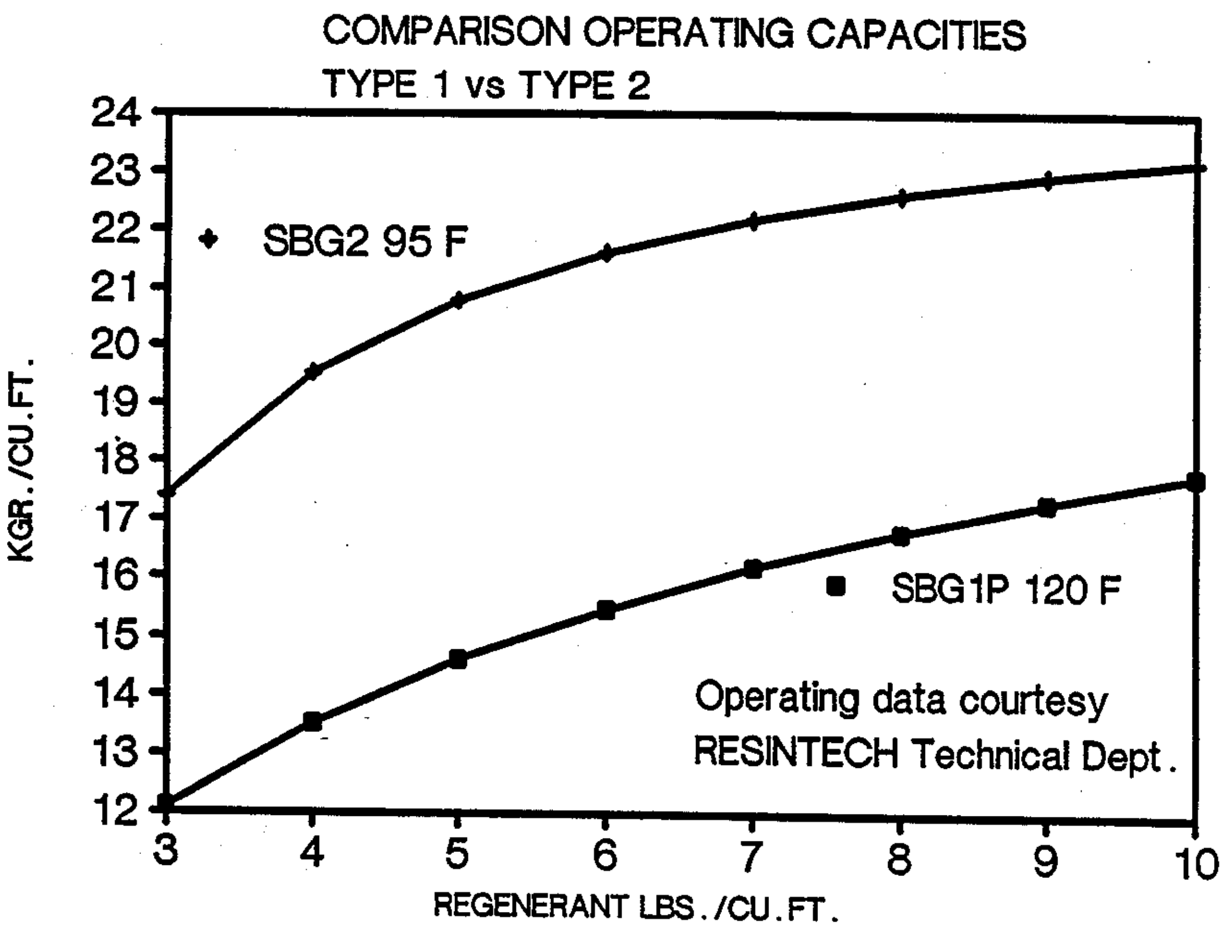
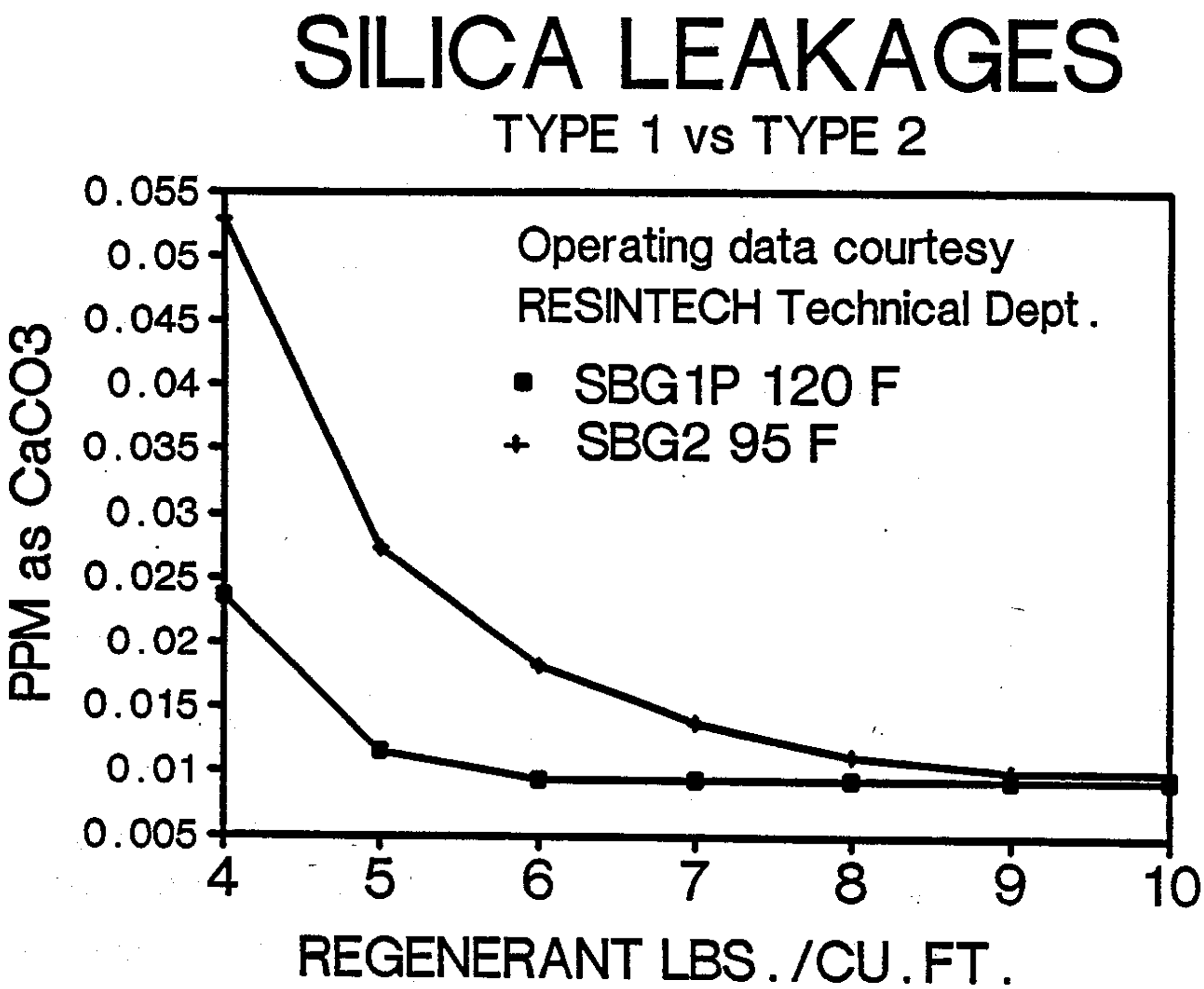

COMPARISON OPERATING CAPACITIES
TYPE 1 vs TYPE 2
KGR./CU.FT.
24
23
22
21
20
19
18
17
16
15
14
13
12
SBG2 95 F
SBG1P 120 F
Operating data courtesy
RESINTECH Technical Dept.
3
4
5
6
7
8
9
10
REGENERANT LBS./CU.FT.

FIGURE 2



SILICA LEAKAGES
TYPE 1 vs TYPE 2
Operating data courtesy
RESINTECH Technical Dept.
SBG1P 120 F
SBG2 95 F
PPM as CaCO3
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
4
5
6
7
8
9
10
REGENERANT LBS./CU.FT.

TABLE 2A

FORM #301

TECHNICAL SURVEY - MULTIPLE BED DEMINERALIZERS FOR ASSISTANCE CALL (609) 429-6620; ask for Mike Gottlieb	COMPANY/LOCATION: ResinTech / N.J. NAME OF INDIVIDUAL: M. Gottlieb PHONE: 609 429-6620

INLET WATER SOURCE..... SURFACE ☒ WELL ☐
TOTAL INLET FLOW RATE....... 300 GPH
NUMBER OF TRAINS............... 3
NORMAL FLOW RATE PER TRAIN .. 150 GPH
DEGASSIFIER or DEAERATOR....... YES ☒ NO ☐

PRETREATMENT TYPE Activated carbon, City water

GALLONS / TRAIN /REGENERATION 238,000 GALS.

EFFLUENT CO_2 6 ppm as CO_2

	CATION	ANION	MIXED BEDS
VESSEL & RESIN BED SIZE			CATION / ANION Ratio ___
DIAMETER (Feet & In.) HEIGHT (Feet & In.)	8 Ft. 0 In. or ___ Ft. ___ In.	7 Ft. 0 In. or ___ Ft. ___ In.	___ Ft. ___ In. or ___ Ft. ___ In.
RESIN BED HEIGHT (Feet & In.) or VOLUME (Cubic Feet) TYPE or BRAND NAME of RESIN	___ Ft. ___ In. or 12.0 Cubic Feet R+H IR120	___ Ft. ___ In. or 7.5 Cubic Feet IRA-402	___ Ft. ___ In. or ___ Cubic Feet ___
REGENERANT INFORMATION CONCENTRATION & TOTAL AMOUNT REGENERATION PROCEDURE	H_2SO_4 ☐ HCl ☐ ___ Lbs (100 % basis) or 40 Gals. at 93 % CO CURR. ☐ COUNTER CUR. ☐ STEP WISE YES ☐ NO ☐	NaOH 460 Lbs (100 % basis) or ___ Gals. at ___ % CO CURR. ☒ COUNTER CUR. ☐ PREHEAT BEDS - YES ☒ NO ☐ Regenerant Temp. 120 Deg. F	ACID ___ Lbs. or ___ Gals. at ___ % NaOH ___ Lbs. or ___ Gals. at ___ %
EFFLUENT QUALITY SPECS SODIUM LEAKAGE - PPM as $CaCO_3$ SILICA LEAKAGE - PPM AS SiO_2 CONDUCTIVITY - MICROMHOS pH	4 $CaCO_3$	Avg. .05 SiO_2 20 MMHOS ___	___ $CaCO_3$ ___ SiO_2 ___ MMHOS ___

INFLUENT WATER ANALYSES

CATIONS	as $CaCO_3$	or as the Ion
Calcium	160	
Magnesium	80	
Sodium	61	
Potassium	2	
Other		

ANIONS	as $CaCO_3$	or as the Ion
Bicarbonates	96	
Carbonates	—	
Carbon Dioxide	—	
Chlorides	137	
Sulfates	70	
Silica		16.1
Other		

CONDUCTIVITY ? MMHOS pH 7.0 TEMP RANGE 45 - 70 DEG F

TABLE 2B

MAXIMUM RAW WATER INLET TEMPERATURE: 90 Deg. F

REGENERANT CHEMICAL COSTS:
(Give weight & concentration basis, i.e. - $.04/lb, 66 Deg. Be.)

Sulfuric acid	$.05/Lb - 100% (pure basis)
Hydrochloric acid	
Sodium hydroxide	$.16/Lb - 100% (pure basis)

RESIN LIFE ASSUMPTIONS OR EXPERIENCE VALUES:

Our computer will automatically assign a useful life estimate of 4.0 years for Type 2 anion resins and 6.0 years for type one anion resins. The default life estimates are based only on rates of thermal and chemical decomposition. Other factors such as fouling are not included. If you prefer to supply other values you can do so below.

Use the following values for resin life when computing replacement costs.

Resin name	Actual interval between rebeds years
R+H IRA 402	6

FIGURE 3

RESINTECH - CAPACITY PROJECTIONS

SBG2 VS SBG1P -NORTHERN CLIMATE, R=95 & 120 F

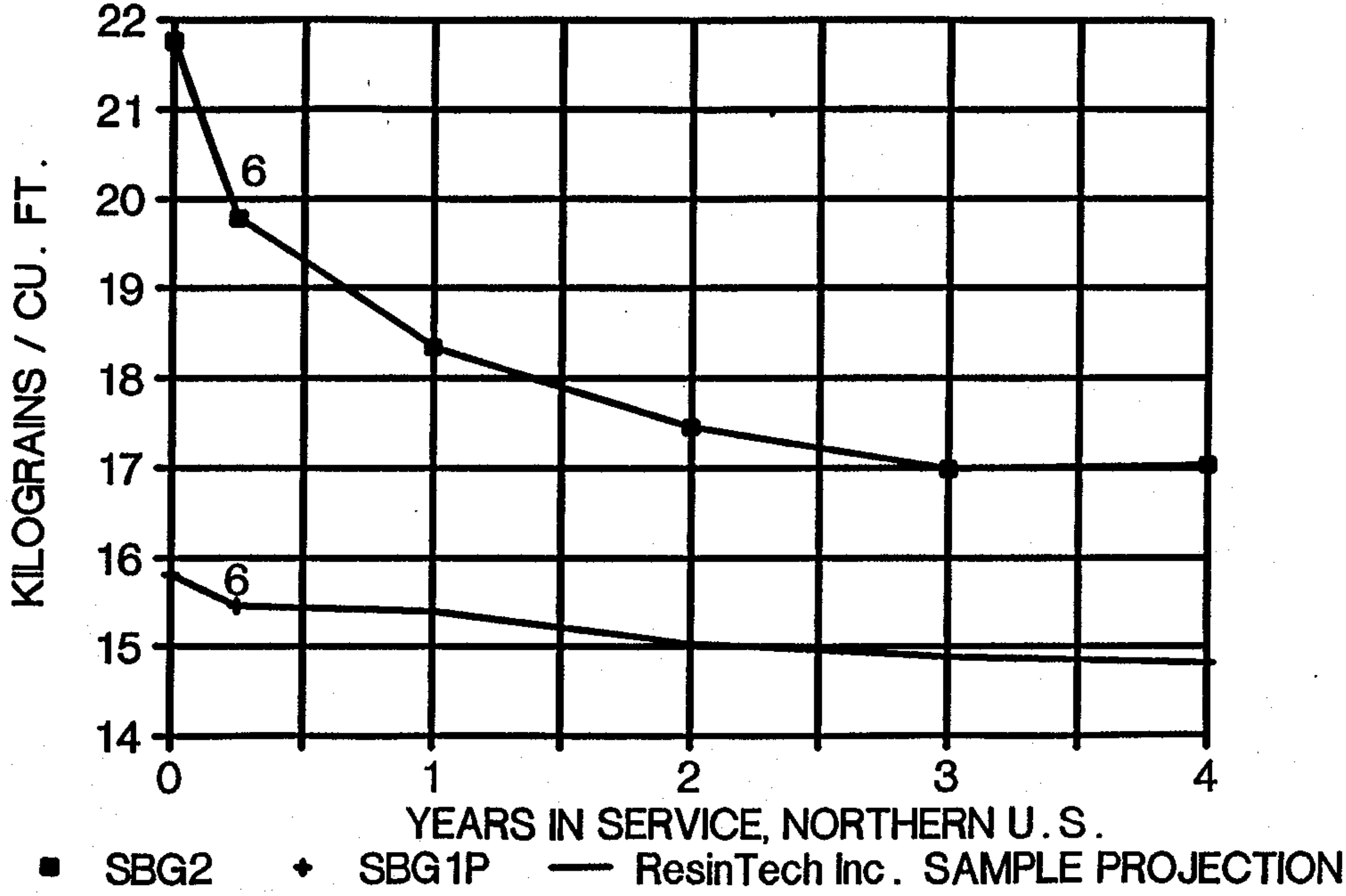


TABLE 3

ResinTech Inc. SAMPLE PROJECTION
PROJECTED OPERATING COSTS FOR ANION RESINS

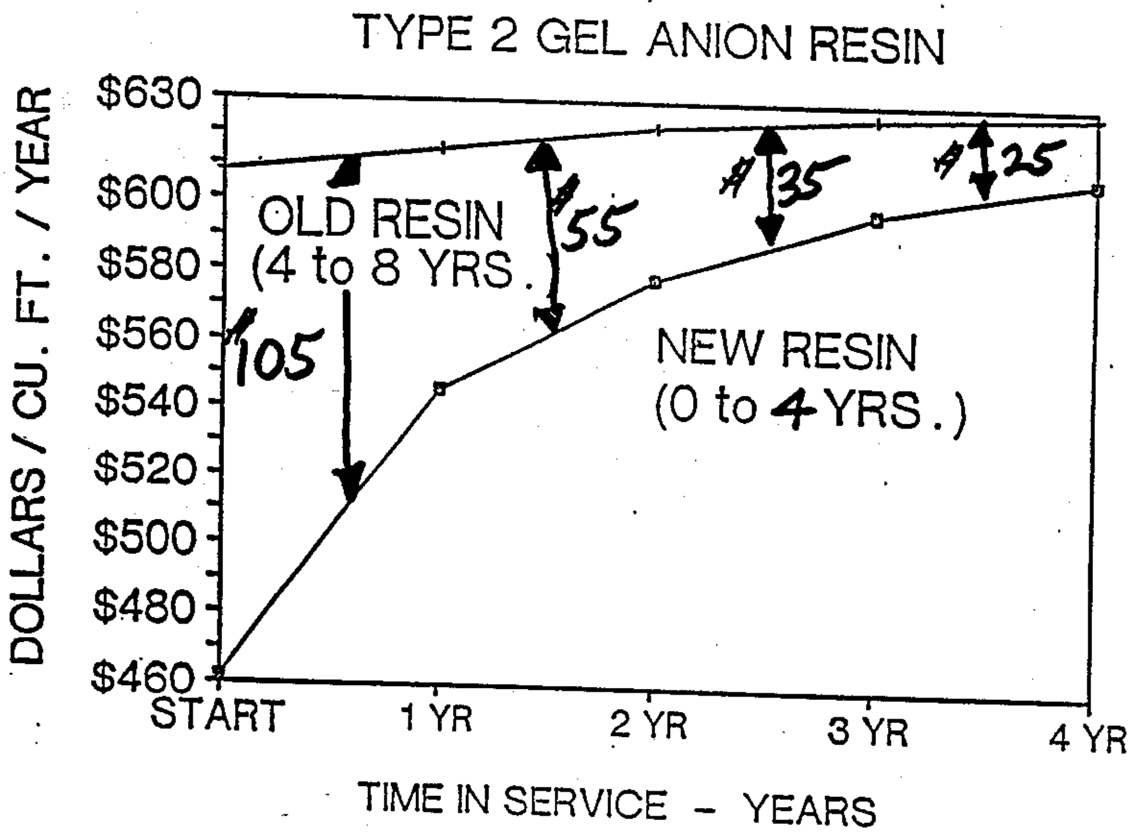
RESINTECH INC.
P.O. Box 966
Cherry Hill, NJ. 08003
TEL: (609) 429-6620
FAX: (609) 429-7987

AVERAGE ANION OPERATING COSTS PER YEAR: REPLACEMENT COSTS INCLUDED PER CUBIC FOOT BASIS

	TYPE ONE GEL Anion Resin Resinex SBG1P	TYPE 2 GEL Anion Resin RESINEX SBG2
REGENERATION COST	$1,183.63	$1,005.14
NEUTRALIZATION COST	$240.33	$189.43
REPLACEMENT COST	$25.00	$37.50
TOTAL (AVERAGE) ANION COSTS $/YR	$1,448.95	$1,232.07
OPERATING CAPACITY Kgrs/cu. ft.		
Initial	15.8	21.8
After 4 yrs.	14.8	17.0
Average	15.1	17.8
REGENERANT DOSE LEVEL- Lbs./Cu. Ft.	6	6
RUN LENGTH - HOURS between regenerations		
Initial	7.1	9.8
After 4 yrs.	6.7	7.7
OPERATING COST ASSUMPTIONS		
Cost of NaOH - $/Lb.	$0.16	$0.16
Cost of Acid- $/Lb.	$0.05	$0.05
Thruput, Gals./cu. ft./ year	1,008,000	1,008,000
Resin Life - Years	6	4

FIGURE 4

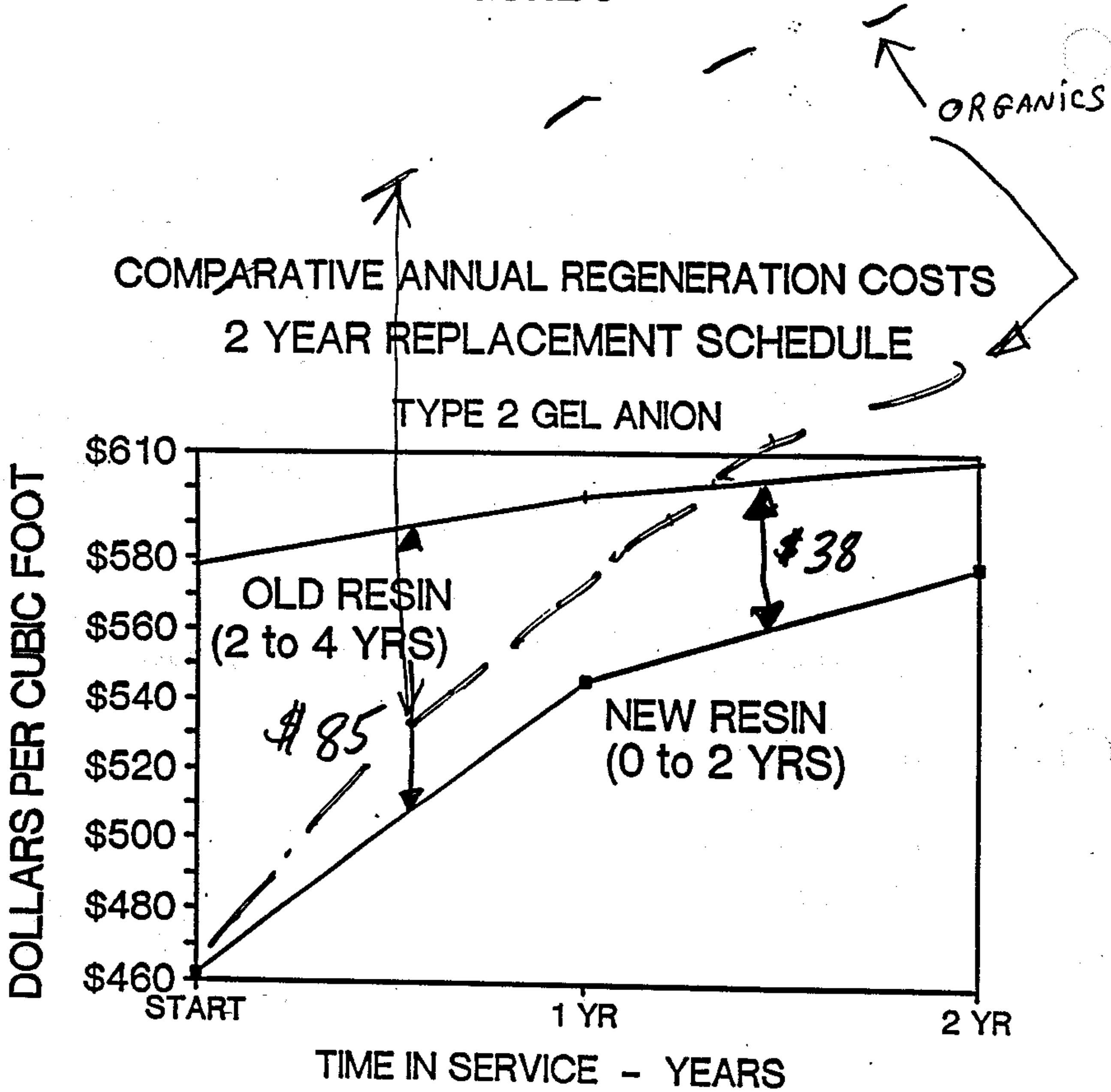
COMPARATIVE ANNUAL REGENERATION COSTS
4 YEAR REPLACEMENT SCHEDULE



REGEN. LEVEL = 5 LBS. / CU. FT.

CUM SAVINGS
year 1 $ 105
2 $ 160
3 $ 195
4 $ 220

FIGURE 5

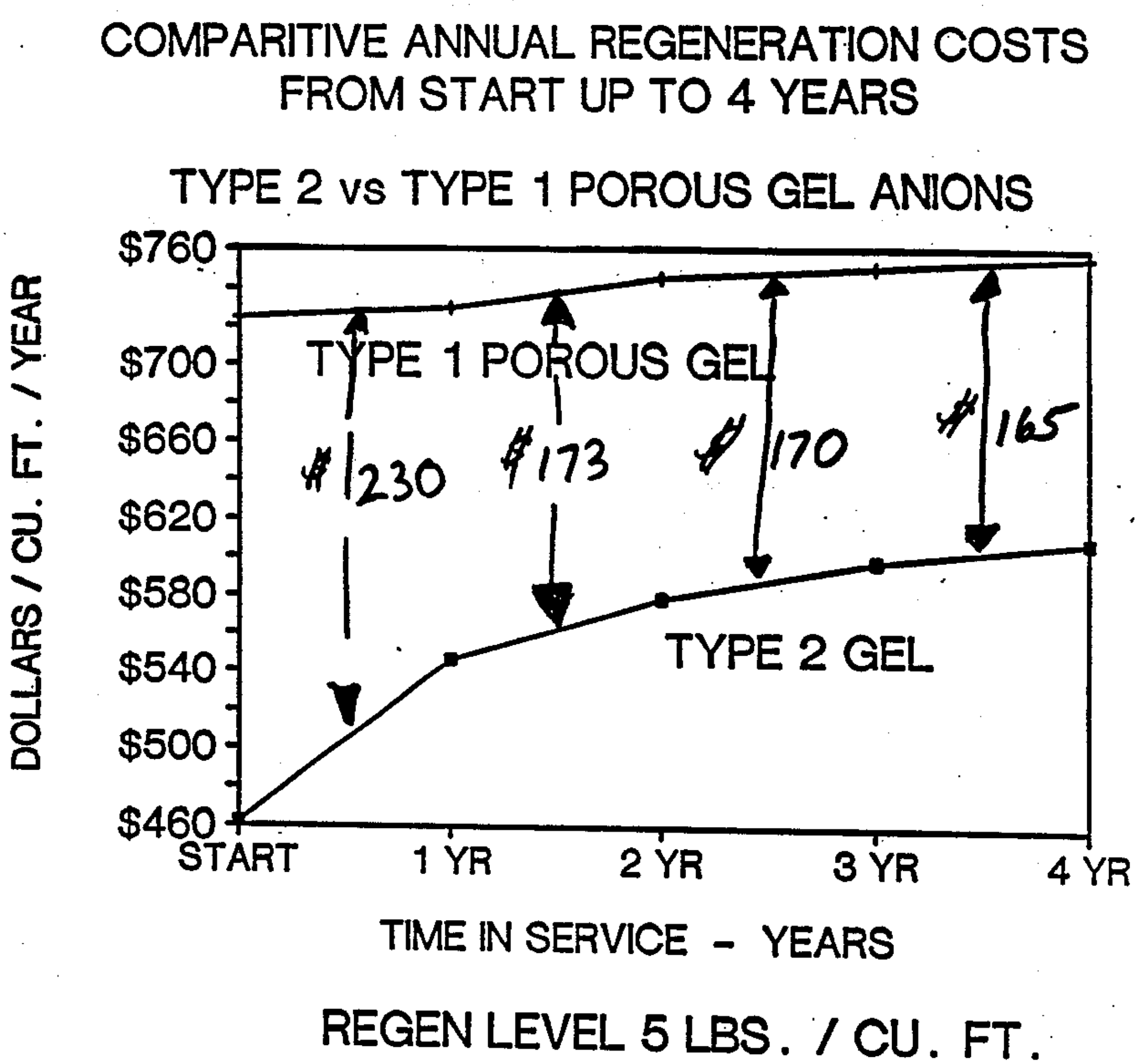


REGEN LEVEL = 5 Lbs. / Cu. Ft.

CUM SAVINGS

		w organics
Year 1	$85	180
2	$123	300

FIGURE 6



CUM SAVINGS

Year 1	$ 230
2	$ 403
3	$ 573
4	$ 738

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INNOVATIONS IN ION EXCHANGE

EQUIVALENT PRODUCT DESIGNATIONS
CLOSEST COMPETITIVE EQIVALENTS

RESINTECH	ROHM & HAAS AMBERLITE	DIAMOND DUOLITE	DOW DOWEX	SYBRON IONAC	PUROLITE
CATION RESINS					
CG8-Na	IR-120 PLUS	C-120	HCR-S	C-249	C-100
CG8-H	IR-120 H	C-20 H	HCRS-H	C-267	C-100 H
CG10-Na	IR-122	C-20x10	HGR	C-250	C100x10
CG10-H	IR-122 H	C-20x10H	HGR-H	C-250H	C100x10H
ANION RESINS					
SBG2	IRA-410	A-104	SAR	ASB2	A-300
SBG1P	IRA-402	A-101D	SBRP	ASB1-P	A-400
SBG1	IRA-400	A-109	SBR	ASB1	A-600
MIXED BED RESINS					
MBED2					NRW-38
NMBED1P	RN-150	ARM-381	MR-3	NM-60	RW-37

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RESINEX™ ION EXCHANGE RESINS

TYPICAL PROPERTIES

PRODUCT	RESIN TYPE	IONIC FORM	APPROXIMATE SHIPPING WT. lbs./cu. ft.	U.S. Std. MESH SIZE	WATER RETENTION %	EXCHANGE CAPACITY MEQ/ML	SPHERICITY %	MAXIMUM TEMPERATURE DEG. F	SWELLING %
Resinex CG8-Na	STRONG ACID GEL	Sodium	52	16/45	45 - 47	2.0	90 - 100	280	Na to H 5
		Hydrogen	50	16/45	49 - 54	1.9	90 - 100	265	Na to H 5
Resinex CG8-Na C		Sodium	52	16/40	45 - 47	2.0	90 - 100	280	Na to H 5
Resinex CG10-Na	STRONG ACID GEL	Sodium	54	16/45	40 - 45	2.1	90 - 100	280	Na to H 5
		Hydrogen	50	16/45	46 - 53	2.0	90 - 100	265	Na to H 5
Resinex CG10-Na C		Sodium	54	16/40	40 - 45	2.1	90 - 100	280	Na to H 5
Resinex SBG1	STRONG BASE TYPE I GEL	Chloride	44	16/45	43 - 47	1.3+	90 - 100	140 (OH) 170 (Cl)	Cl to OH 15
Resinex SBG1 C		Chloride	44	16/40	43 - 47	1.3+	90 - 100	140 (OH) 170 (Cl)	Cl to OH 15
Resinex SBG1P	STRONG BASE TYPE I GEL	Chloride	43	16/45	51 - 56	1.3	90 - 100	140 (OH) 170 (Cl)	Cl to OH 20
Resinex SBG1P C		Chloride	43	16/40	51 - 56	1.3	90 - 100	140 (OH) 170 (Cl)	Cl to OH 20
Resinex SBG2	STRONG BASE TYPE II GEL	Chloride	44	16/45	38 - 44	1.4+	95 - 100	95 (OH) 170 (Cl)	Cl to OH 10 - 13

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COMPARITIVE PROPERTIES
RESINTECH ION EXCHANGE

PROPERTIES	RESINTECH CG8	ROHM & HAAS IR120	DOW* HCR
Ionic Forms	Na^+	Na^+	H^+
Moisture Content (%)	45-49	46	50-56
pH range	0-14	0-14	0-14
Total Capacity (meq/ml)	1.9	1.9	1.8
Sphericity %	95+	N.L	90+
Effective Size (mm)	.5	5.5	.52
+16 mesh (%)	<5	N/L	<5
-40 mesh (%)	<2	N/L	<6
-50 mesh (%)	<1	<1	<1

*Dow sales spec 23095

PROPERTIES	RESINTECH CG10	ROHM & HAAS IR122	DOW* HGR
Ionic Forms	Na^+	Na^+	H^+
Moisture Content (%)	40-44	42	46-50
pH range	0-14	0-14	0-14
Total Capacity (meq/ml)	2.1	2.1	2.0
Sphericity %	95+	N.L	90+
Effective Size (mm)	.55	.54	.53
+16 mesh (%)	<5	N/L	<2
-40 mesh (%)	<2	N/L	<5
-50 mesh (%)	<1	<1	N/L

*Dow sales spec 23095

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COMPARITIVE PROPERTIES
RESINTECH ION EXCHANGE

PROPERTIES	RESINTECH SBG1P	ROHM & HAAS IRA-402	DOW* SBR-P
Ionic Forms	CL^-	CL^-	CL^-
Moisture Content (%)	51-56	54	53-60
pH range	0-14	0-14	0-14
Total Capacity (meq/ml)	1.2-1.3	1.3	1.2
Sphericity %	95+	N.L	90+
Effective Size (mm)	.5	.5	.50
+16 mesh (%)	<5	N/L	N/L
-40 mesh (%)	<2	N/L	N/L
-50 mesh (%)	<1	<1	<2

*Dow sales spec 23095

PROPERTIES	RESINTECH SBG2	ROHM & HAAS IRA-410	DOW* SAR
Ionic Forms	CL^-	CL^-	CL^-
Moisture Content (%)	38-44	42	38-45
pH range	0-14	0-14	0-14
Total Capacity (meq/ml)	1.4	1.4	1.4
Sphericity %	95+	N.L	80+
Effective Size (mm)	.55	.48	.55
+16 mesh (%)	<5	N/L	<5
-40 mesh (%)	<2	N/L	N/L
-50 mesh (%)<1	<1	<3	

*Dow sales specs 22826

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