

# RELATIVE CONTRIBUTIONS FROM THE BINDER AND THE AGGREGATE TO OXIDATION IMPURITY LEVELS IN A MODEL ANODE BINDER MATRIX

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## Abstract

The study investigates the influence of oxidation catalyst impurity levels in recycled anode carbon and the relatively low levels in anode binders, and their combined effect on the concentrations in the carbonised binder matrix. The results highlight the critical importance of butt-cleaning procedures. Binder pitch was mixed separately with graded aggregate containing several levels of bath impurity then co-carbonised to 1080°C in a simplified system based on an industrial anode.

The graded aggregate was prepared either from anode butt material or from low impurity, unelectrolysed baked anode. Samples of the carbonised binder matrix were subsequently reclaimed for elemental analysis and carbon dioxide reactivity tests. Even after allowance for baking losses, oxidation impurity levels are much higher in the carbonised binder matrix compared with the original pitch. Impurity levels in the reclaimed binder matrix are sensitive to, and dominated by, the concentration of “key” catalyst elements in the aggregate. The findings re-emphasise the need for rigorous butt cleaning routines and must make smelters that re-use cathodic butts and burn-offs reconsider whether a recalculated cost benefit analysis justifies switching to a non-anode disposal route.

## Introduction.

Considerable amounts of anode carbon are wasted in unwanted side reactions such as excess consumption by air and CO<sub>2</sub>. Through selective oxidation of the more reactive binder matrix filler particles are detached from the anode. This “dusting” process also contributes to the excess anode consumption as well as potentially reducing energy efficiency and adding to workforce pot tending duties through more pot skimming.

This study examines the influence of different sodium and calcium sources on impurity levels in the binder matrix, which is selectively oxidised during smelting, as stated above.

The purity of individual raw materials in an anode is important; it is one of the parameters along with structure and porosity in the PSP model (1). In this context recycled anode butt carbon constitutes an important raw material. The anode must be viewed as a whole and not just individual components in isolation because these components can interact at the green and baked stages, as this paper will show. There are several authoritative publications on the importance of impurities in filler coke (2-7). There are fewer publications for pitch binder (8, 9) in an industrial context.

The concentration of sodium and calcium, (which act as oxidation catalysts) is much higher in anode butt than it is in anode quality binder pitch, see Table 2. If it can be shown that

these and other impurities migrate from recycled butt to the binder matrix, then the level of elemental impurity in binder pitch may be much less important to the anode. Impurity levels in recycled anode butt material would then take on even more importance both in terms of cleaning practices and in not recycling cathodic butts or others heavily impregnated with bath material. These factors are in addition to butt crushing practices designed to minimise butt contents in the finer aggregate fractions, particularly mill dust.

In this study, the binder matrix is defined as the carbonised pitch present after baking in a small scale simplified model mixture of a single size fraction of filler grains and pitch. Milled dust was deliberately excluded, so was virgin coke. The fact that virgin coke constitutes the vast majority of the anode is recognised, but since this is a model experiment, coke would impede and confuse the investigation. The fillers were chosen to represent three levels of impurity, namely high impurity butt (representing practice 10 or 15 years ago), modern butt material (representing typical current practice) and carefully prepared low impurity baked anode.

The impurity analysis results for the binder matrix have major ramifications for industrial anode quality and performance. These results form the centrepiece of this paper.

### **Experimental**

The properties for the two industrial pitches used in the study are in Table 1

**Preparation of Filler carbon** The three carbon fillers were prepared from large, multi kilogram pieces supplied at various times by an aluminium smelter. See Table 2

The low impurity filler (LIBA) was prepared from baked, unelectrolysed industrial anode. Particular measures were taken to minimise the inclusion of recycle butt content. Intermediate impurity filler is well-cleaned anode butt material (NIAB), which represents good industrial practice today. High impurity filler (HIAB) was derived from anode butt collected some 10 years ago when cleaning practices were less rigorous, and represents the historic situation or the scenario when either cleaning practices fail to meet the standard or a bad butt slips through the system.

None of the filler carbons were artificially doped with bath chemical; all were “as-received” industrial anode carbon. It is this feature that makes the findings in this paper directly relevant to the anode and aluminium smelting industries.

The objective of the filler preparation procedure was to maximise the yield of filler grains in the target size range of 1.7 to 2.36 mm and minimise creation of under-size material by only reducing the laboratory jaw crusher aperture in small steps to gradually reduce the grain size. The target fraction was sieved out and retained after each pass through the crusher. Sub-1.7 mm grains were removed after each pass and discarded. Oversize grains were re-crushed and re-sieved until it was all used up. Cross contamination was addressed through thorough cleaning of equipment.

Prior to mixing with the pitch, the fillers were air jetted to remove surface dust from the grains

**Mixing pitch and carbon filler.** Individual fillers were gently hand stirred with the pitch binder to minimise the risk of abrading or breaking the grains. Mixtures of pitch and filler were fused at above pitch softening point temperature then carbonised to 1080°C according to a standard programme (10) under a mildly reducing atmosphere.

**Reclaiming Binder matrix Material.** The reclamation procedure takes advantage of the fact that the filler material is much harder than the baked pitch, the “binder matrix” defined above. A 1.14 mm aperture stainless steel mesh sieve was used to reclaim binder matrix. This aperture was deliberately chosen to give a one-sieve size gap. 1.36 mm, as a cut-off to prevent very asymmetric or fissured filler grains ‘breaking through’. Binder matrix carbon was analysed as required.

**Pitch testing and binder matrix analysis.** Pitches prior to carbonisation were tested by published ISO methods except for softening point which was measured using ASTM D 3104 (Mettler). Elemental impurities were analysed by ICP using petroleum cokes as standards. Sulphur in pitch and reclaimed binder matrix was measured using BS 6043:Section 1.13.

**Physical transfer markers.** The cornerstone of the experimental protocol was to demonstrate that any redistribution of elements from filler to binder matrix, or vice-versa, was indeed migration (or transport) and not simply ‘plucking’ of the filler particle surfaces. Nickel and vanadium were elemental markers present at much higher levels in petroleum derived filler than they are in coal derived binder pitch and acted as sensitive barometers. See Tables 1 and 2. The results show clearly that in nearly all cases there was less than 5% transfer of markers to the matrix. This vindicated the simple experimental binder matrix reclamation procedure.

### **Results and Discussion.**

The study includes two different pitch binders, three levels of impurity in the filler carbon and three levels of pitch addition so far. See Tables 1 and 2.

**Table I Pitch Properties**

Property	Binder Pitch 1	Binder Pitch 2
Mettler S. Pt °C	116.2	118.8
Alcan Coking Value %	58.2	58.6
Density gcm-3 @25 °C	1.319	1.322
Quinoline Insolubles, %	6.4	7.9
Toluene Insolubles, %	27.8	28.4
Sulphur %	0.51	0.58
Ash %	0.27	0.21
Sodium ppm	180	104
Calcium ppm	160	58
Nickel, ppm	5	6
Vanadium, ppm	8	8
Aluminium, ppm	120	120

ISO methods except for elements by ICP, sulphur by BS 6043: Section 1.13:1994 and S.Pt. by ASTM D 3104.

**Table II Properties of Fillers prepared from Butts and**

### Baked Anode

Element, ppm	Filler from HIGH IMPURITY Anode Butt	Filler from NORMAL IMPURITY Anode Butt	Filler from LOW IMPURITY Baked Anode
Designation	HIAB	NIAB	LIBA
Sodium	3485	1430	440
Calcium	480	255	140
Nickel	86	90	90
Vanadium	60	71	100
Aluminium	2940	1130	540
Sulphur, %	1.3	1.2	1.4

Elements analysed by ICP except sulphur by BS 6043: Section 1.13:1994 combustion type method

The first set of experiments were carried out by mixing 25% Binder Pitch 1 (Table 1) with each of the 3 carbon filler materials. Each experiment was duplicated and the results are shown in Table 3

At the highest level of filler carbon impurity (HIAB), the

reclaimed carbonised binder matrix carbon contains 12 times more sodium, and 4 times more calcium, than is simply explained by concentration of the pitch impurity levels [ $100 \times (180/\text{Pitch Carbonisation yield } \%)$  i.e. 290 ppm]

In absolute terms the sodium concentration is a massive 3750 ppm with calcium at a tremendous level of over 800 ppm. We calculate that around 20% of the sodium and calcium originally present in the butt filler must have moved into the binder matrix in these experiments.

The marker elements vanadium and nickel are at low concentration in the binder matrix and show that simple cross-contamination with filler carbon, by mechanical transfer ("plucking") is not the explanation for these remarkable and far-reaching findings. Aluminium, a pacifier, also appears to move towards the binder matrix.

Using butt material cleaned to a good industrial standard (NIAB), sodium levels in the reclaimed binder matrix rise to between 1200 and 1600 ppm, and the calcium level rises to 500 ppm (Table 3). Thus even this good quality filler material contributes between 4 and 6 times more sodium, and at least double the amount of calcium to the binder matrix, compared to the pitch contribution.

**Table III Elemental Impurities in Recovered Binder Matrix**  
**25% addition of Pitch 1 to each filler separately. This part of study is to show that the experiment can be replicated**

Binder	Elemental concentrations, ppm				Elemental concentrations, ppm					
	Sodium		Calcium		Nickel		Vanadium		Aluminium	
	First	Second	First	Second	First	Second	First	Second	First	Second
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'HIGH IMPURITY' Anode butt HIAB</b>										
Pitch content of paste % w/w	24.9	24.9	25.0	25.0	24.9	24.9	24.9	24.9	24.9	24.9
Carbonised pitch yield % w/w	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1	62.1
Experimental concn. by ICP	3746	3758	879	807	34	20	25.4	23.6	1413	492
Projected if no migration/other transfer	290	290	258	258	10	10	13	13	193	193
Calculated transfer (migration) % from filler to binder matrix to explain experimental result	20.4	20.5	26.8	23.7	5.8	2.5	4.3	3.7	8.5	2.1
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'NORMAL IMPURITY' anode butt NIAB</b>										
Pitch content of paste % w/w	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
Carbonised pitch yield % w/w	64.1	64.1	64.1	64.05	64.1	64.1	64.1	64.1	64.1	64.1
Experimental concn. by ICP	1644	1160	465	518	31	9	24	22	881	260
Projected if no migration/other transfer	281	281	250	250	9	9	12	12	187	187
Calculated transfer (migration) % from filler to binder matrix to explain experimental result	20.3	13.1	18.0	22.3	5.1	0.0	3.4	2.8	13.0	1.4
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'LOW IMPURITY' Baked Anode LIBA</b>										
Pitch content of paste % w/w	25	25	25	25	24	24	25	25	25	25
Carbonised pitch yield % w/w	68.5	68.4	68.5	68.4	68.5	68.4	68.5	68.4	68.5	68.4
Experimental concn. by ICP	586	579	204	200	34	9	14	30	314	66
Projected if no migration/other transfer	263	263	234	234	9	9	12	12	175	175
Calculated transfer (migration) % from filler to binder matrix to explain experimental result	16.8	16.4	-4.8	-5.5	6.1	0.0	0.5	4.3	5.9	-4.6

At the lowest filler carbon impurity level (LIBA), the sodium level in the reclaimed binder matrix carbon is still more than double that expected from the pitch contribution.

Curiously, there is an apparent 5% migration of Ca **out** of the binder matrix. However, in this case, the filler carbon calcium concentration, at 140 ppm, is lower than the 234 ppm expected from carbonisation of the pitch, and thus, in this case only, the concentration gradient between filler carbon and binder matrix is reversed. Thus in all cases, any apparent migration is related to the concentration gradient between filler carbon and carbonised binder matrix.

Comparison of the duplicate tests in Table 3 shows the data are repeatable. The results also show very low levels of mechanical transfer of Ni and V, indicating only minor contamination of the reclaimed binder matrix by “plucked” filler carbon.

Pitch interacts in liquid form with the filler so the next objective was to explore sensitivity to increasing and decreasing the binder addition. Experiments with 20% w/w and 30% w/w pitch present in the mixture bracket the original level and represent under and over-pitching conditions. The results in Table 4 again show the general pattern of Na and Ca migration, with the use of higher impurity level filler material resulting in greater transfer. The proportion of binder also has an effect, with greater % migration at higher pitching rates, albeit that the absolute concentration levels decrease with increasing pitching rate. Thus, in addition to the migration

induced by concentration gradients, there is also a partition effect.

The actual percentage of sodium and calcium transferring from the filler to the matrix is calculated at 28.3% when the pitch addition was 30% w/w compared with 22.7% when addition of pitch was only 20%. The amount of transfer shows less sensitivity to binder level than might have been expected. When there is sufficient target impurity element available in the anode filler carbon then the transfer (migration) mechanism is not solely dictated by surface area considerations, which are constant, but by the size of the pitch reservoir available to accept the migration of both sodium and calcium oxidation catalyst elements. Once again, the level of sodium and calcium impurities in the as-produced pitch is overwhelmed by the quantity moving into the binder matrix from the filler, subject to those elements being available. This is certainly the case with the high impurity butt (HIAB) and for the current industry standard, cleaned, hard, sound butt recycle (NIAB).

The amount of cross-contamination of the binder matrix carbon by filler carbon is again low, as witnessed by the low transfer of Ni and V (generally below 6%), as shown in Table 4. The data hints that simple physical transfer is a little higher at the lowest 20% pitch addition level. This is in accord with logical expectation because the coating on the filler has to be thinner and may not be complete, so ‘plucking’ or physical abrasion is not unexpected. This finding boosts confidence in the robustness of the binder matrix reclamation procedure.

**Table IV Sensitivity to Binder Content of Paste**

**Pitch 1 mixed separately with all three fillers, carbonised to 1080°C then binder matrix reclaimed and analysed**

Binder Content of Paste	Elemental concentrations. ppm						Elemental concentration, ppm								
	Sodium			Calcium			Nickel			Vanadium			Aluminium		
	20	25	30	20	25	30	20	25	30	20	25	30	20	25	30
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'HIGH IMPURITY' Anode Butt HIAB</b>															
Pitch content of paste % w/w	19.9	24.9	30.0	19.9	25.0	29.9	19.9	24.9	30.0	19.9	24.9	19.9	24.9	24.9	24.9
Carbonised pitch yield % w/w	61.3	62.1	60.8	61.3	62.1	60.8	61.3	62.1	60.8	61.3	62.1	60.8	61.3	62.1	60.8
Experimental concn. by ICP	5482	3758	4036	1035	807	889	15	20	10	21	24	26	828	492	478
Projected if no migration/other transfer	294	290	255	261	258	263	10	10	10	13	13	13	196	193	197
Calculated transfer (migration) % from Filler to Binder Matrix to explain experimental result	22.7	20.5	28.3	24.6	23.7	33.8	2.5	4.6	2.9	3.3	4.9	3.9	31.2	18.8	17.8
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'NORMAL IMPURITY' Anode Butt NIAB</b>															
Pitch content of paste % w/w	19.9	24.9	29.9	19.9	24.9	29.9	19.9	24.9	24.9	19.9	24.9	19.9	19.9	24.9	24.9
Carbonised pitch yield % w/w	62.85	64.05	61.95	62.85	64.05	61.95	62.85	64.05	61.95	62.85	64.05	61.95	62.85	64.05	61.95
Experimental concn. by ICP	1430	1160	1013	577	518	549	10.8	9	25	31	22	26	206	260	43
Projected if no migration/other transfer	286	281	250	255	250	258	10	9	10	13	12	13	191	187	194
Calculated transfer (migration) % from Filler to Binder Matrix to explain experimental result	12.5	13.1	14.1	19.7	22.3	30.1	1.9	2.2	5.7	6.8	6.6	5.7	2.8	4.9	0.8
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'LOW IMPURITY' Baked Anode LIBA</b>															
Pitch content of paste % w/w	20.0	25	29.9	20.0	25	29.9	20	24	24	20	25	20	20	25	25
Carbonised pitch yield % w/w	65.75	68.4	65.8	65.75	68.4	65.8	65.75	68.4	65.8	65.75	68.4	65.8	65.75	68.4	65.8
Experimental concn. by ICP	599	579	514	248	200	208	50	9	22	40	30	26	435	66	227
Projected if no migration/other transfer	274	263	236	243	234	243	9	9	9	12	12	12	183	175	182
Calculated transfer (migration) % from Filler to Binder Matrix to explain experimental result	12.2	16.4	17.7	0.5	-5.5	-7.0	<b>9.0</b>	<b>2.1</b>	<b>5.1</b>	<b>9.3</b>	<b>9.8</b>	<b>6.1</b>	<b>6.3</b>	<b>1.3</b>	<b>4.4</b>

The experimental series to examine the effect of filler carbon impurity level and pitching rate was then repeated, with a different source of pitch (Binder Pitch 2 in Table 1).

The results, presented in Table 5, show exactly comparable trends to the earlier series (Table 4). Thus, for example, the HIAB/20% Binder Pitch 2 combination resulted in 6943 ppm sodium and 1363 ppm calcium in the reclaimed binder matrix, representing a 37-fold and 13-fold increase respectively in the

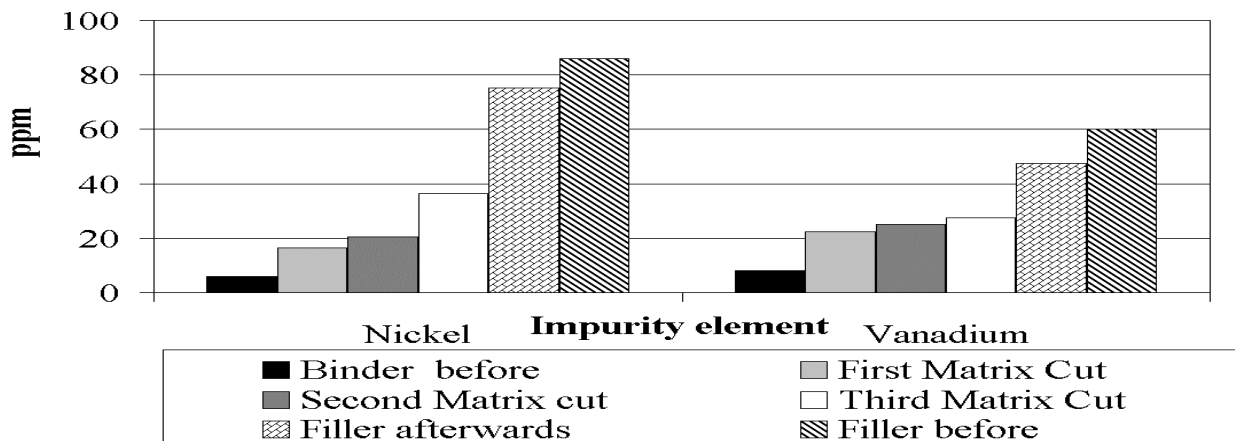
The LIAB/20% Binder Pitch 2 combination resulted in 400-ppm sodium and 188 ppm calcium in the reclaimed binder matrix, representing roughly a 2-fold increase on the levels expected from the pitch impurity levels.

With the normal industry standard NIAB material, the figures are 1430 and 577 ppm respectively, 5 times and just over twice the pitch contribution. Put another way, the pitch contributes only 20% and 44% respectively, of the sodium and calcium present in the carbonised binder matrix. Therefore oxidation

**Table V Impurity Transfer when using a Second Pitch and Sensitivity to Paste Binder Content**  
**Pitch 2 mixed separately with all three fillers, carbonised to 1080°C then binder matrix reclaimed and analysed**

Binder content of paste	Elemental concentrations, ppm									Elemental concentrations, ppm					
	Sodium			Calcium			Nickel			Vanadium			Aluminium		
	20	25	30	20	25	30	20	25	30	20	25	30	20	25	30
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'HIGH IMPURITY' Anode butt HIAB</b>															
Pitch content of paste % w/w	19.9	24.9	30.0	19.9	25.0	29.9	19.9	24.9	29.9	19.9	24.9	29.9	19.9	24.9	29.9
Carbonised pitch yield % w/w	61.5	62.1	60.8	61.5	62.1	60.8	61.5	62.1	40.5	61.5	62.1	23.4	61.5	62.1	62.1
Experimental concn. by ICP	6943	4850	4279	1363	962	691	32	21	24	20	24	23.5	4998	3713	647
Projected if no migration/other transfer	187	167	171	106	93	95	7	10	15	8	13	34	203	193	193
Calculated transfer (migration) % from filler to Binder Matrix to explain experimental result	29.7	27.7	30.7	40.4	37.5	32.2	7.4	4.4	4.6	4.9	6.1	-7.6	40.5	39.7	6.6
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'NORMAL IMPURITY' anode butt NIAB</b>															
Pitch content of paste % w/w	19.9	24.9	29.9	19.9	24.9	29.9	19.9	24.9	29.9	19.9	24.9	29.9	19.9	24.9	29.9
Carbonised pitch yield % w/w	60.8	64.05	61.95	60.8	64.05	61.95	60.8	64.1	64.1	60.8	64.1	62.8	60.8	64.1	64.1
Experimental concn. by ICP	1502	1277	1138	522	488	414	18	15	9	31	23	22	137	230	236
Projected if no migration/other transfer	189	162	168	107	91	94	7	9	9	8	12	13	206	187	187
Calculated transfer (migration) % from filler to Binder Matrix to explain experimental result	14.1	16.6	17.9	25.3	33.1	33.2	3.2	2.1	-0.1	8.0	4.9	5.6	-1.5	1.2	1.8
<b>Binder Matrix Reclaimed after Pitch Carbonised with 'LOW IMPURITY' Baked Anode LIAB</b>															
Pitch content of paste % w/w	20.0	25	29.9	20.0	25	29.9	20	24	29.9	20	25	29.9	20	25	29.9
Carbonised pitch yield % w/w	66.6	68.4	65.8	65.2	68.4	65.8	65.2	71.8	71.8	65.2	71.8	65.7	65.2	71.8	71.8
Experimental concn. by ICP	400	356	327	188	160	214	34	6	16	37	25	20	311	227	315
Projected if no migration/other transfer	173	152	158	100	85	88	6	8	8	8	11	12	192	167	167
Calculated transfer (migration) % from filler to Binder Matrix to explain experimental result	9.2	10.6	10.8	11.5	12.3	25.2	7.6	-0.7	3.6	7.2	4.5	3.1	5.5	3.7	11.7

**Figure 1 Proving the Matrix Reclaim Protocol & showing Marker Element Build Up from HIGH IMPURITY Grains Experiment**



levels predicted from the pitch impurity levels.

**Table VI Elemental Impurities in Three Cut Reclaim of Binder Matrix and Trial Mass Balance for Impurities**

	Sodium ppm	Calcium ppm	Nickel ppm	Vanadium ppm	Aluminium ppm
First Matrix cut	1313	507	15.1	16.0	656
Second Matrix Cut	1342	501	40.5	21.5	685
Third Matrix Cut	1358	539	51.0	28.5	1338
Filler remaining	903	185	75.2	67.1	183
Filler before	1430	255	90	71	1130
Binder Pitch before	180	160	6	8	120
Pro-rata sum (concentration*weight) for carbonised matrix and filler	967	234	64.0	57.1	288
Pro-rata sum (concn.*wt.) for binder & filler before Carbonisation	1117	231	69.0	60.3	877

**Table VII Binder Matrix Reactivity at 960°C to Carbon Dioxide in Empirical Adapted Calcined Coke Test**

Binder Matrix Origin	Residue after CO <sub>2</sub> Reactivity % w/w		Binder Matrix Analysis ppm unless stated otherwise					Sulphur %
	Run 1	Run 2	Sodium	Calcium	Nickel	Vanadium	Aluminium	
Carbonised with HIAB	41.7	41.9	3746	779	34	25.4	1413	0.47
Carbonised with NIAB	57.9	58.8	1644	485	31	24	881	0.43
Carbonised with LIBA	67.4	68.8	586	204	34	14	314	0.52

catalyst levels in the carbonised binder matrix are relatively insensitive to specification limits chosen for pitch.

Once again the transfer of vanadium and nickel markers to the reclaimed binder matrix was between 7% to the matrix and 7% in the opposite direction again showing that simple physical transfer is a minor factor.

Since the evidence for systematic mass transfer of Na and Ca relies so heavily on there being no cross-contamination of the reclaimed binder matrix carbon, it was decided to attempt to prove the experimental protocol.

The experiment was designed to show that successively more severe reclamation conditions would eventually result in physical cross-contamination, and this would be accompanied by noticeable changes in Ni and V concentration.

The data, Table 6 and Figure 1, show that more severe conditions do eventually lead to such physical break-through, and thus we can be confident that the mild reclamation

conditions normally used do not result in significant contamination.

The data in Table 6 also show, within very reasonable limits, how good the mass-balance agrees.

The mass balance is unexpectedly good for four out of the five elements; aluminium could come from alumina, the fluoride or even "metal splash" so it is not surprising that there is more scatter in the data.

High concentrations of oxidation catalysts in the binder matrix point strongly towards increased reactivity in the binder matrix caused by migration of sodium and calcium from butts recycle but it is not a rigorously conclusive demonstration. This last hurdle requires reactivity information. Reactivity at 960°C to carbon dioxide was measured using R&D Carbon Ltd. coke testing equipment operated at only 960°C for one hour. Qualitative inspection of the data, (Table 7 above), shows that pacifying sulphur levels are similar, so this factor is not a major consideration. Binder matrix reclaimed after bake with high impurity anode butt had the highest gas weight loss and the

matrix recovered from the experiment with low impurity baked anode had the lowest weight loss. The results have been replicated. There is no attempt at statistical relationships between reactivity and impurity level for various oxidation catalyst elements because the data are too few.

The future direction for this study is clear because it is ultimately reactivity that is industrially important, not the intrinsic sodium or calcium levels because they have no direct influence on specific energy consumption (KwH/KgAl) or metal purity.

### **Conclusions**

There appears to be no upper limit value for the concentration of sodium and calcium in the binder matrix. The higher the level in the aggregate, the higher will be the concentration in the binder matrix after carbonisation.

This finding has important repercussions for the anode carbon industry. It creates a demonstrable incentive for anode producers to achieve and maintain a high general standard of butt cleaning and to pay equal attention to preventing the recycling of any anode carbon that may be particularly high in electrolyte.

The pitch sodium and calcium concentrations are a small, minor contribution to the level in the binder matrix, so the importance of these properties in specifying and rating prebake anode binder pitch becomes almost irrelevant.

Approximately one-quarter of the sodium in each of the three filler aggregates has transferred to the binder matrix, probably driven by the concentration gradient. The conclusion is the same for calcium in the experiments with normal and high impurity butt recycle carbon.

The finding that there is no transfer of calcium into the matrix when the aggregate is 'very low impurity' baked anode could be explained by no gradient to drive calcium into the matrix.

Simple physical transfer is low at generally less than 6% to 12% according to Nickel and Vanadium markers used to estimate 'plucking' during reclamation of carbonised binder matrix. These findings validate the experimental design and protocol.

Aluminium, a pacifier, is again also present in the binder matrix at much higher levels than can be accounted for by simple concentration during pitch carbonisation but levels are more variable, possibly because the elemental aluminium can have several origins in an anode.

### **Acknowledgements**

The author gratefully acknowledges Anglesey Aluminium Metal Limited's willing co-operation and the enthusiastic and expert analysis work by their Chemists, whose ICP analysis is central to this paper. Likewise Conoco Humber Refinery who willingly provided facilities and their help with completing the CO<sub>2</sub> reactivity tests. Last but not least I recognise the contributions from colleagues in Koppers, particularly Angela Richardson.

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