GM 27382

LE MARCHE MONDIAL DU VANADIUM

GOUVERNEMENT DU QUÉBEC

MINISTÈRE DES RICHESSES NATURELLES

MEMORANDUM

À: Dr J.-E. Gilbert, Sous-ministre **DATE:** Le 6 octobre 1971.

DE: Michel Bussière, Directeur du Bureau de Planification

SUJET: LE VANADIUM CONTENU DANS LE GISEMENT DU CANTON DE RINFRET

La lecture du mémoire ci-joint, "Le marché mondial du vanadium" par Christian Leman, fait ressortir des points majeurs dont l'exploitant du gisement du Canton de Rinfret devra tenir compte, à savoir:

1- la faiblesse financière relative de l'industrie du vanadium. A l'échelle mondiale, cette industrie a approximativement un chiffre d'affaires de $40 millions;

2- l'intégration du secteur. Cette industrie ne possède que sept exploitants de gisements dont cinq sont, en même temps, producteurs et consommateurs;

3- la difficulté technique d'extraire seulement le vanadium. A moins que le gisement n'ait une haute teneur, les techniques actuelles ne permettent pas d'exploiter rentablement un gisement seulement pour le vanadium. On doit valoriser les autres produits;

4- la saturation du marché. Depuis juin 1970, le prix du vanadium baisse régulièrement afin d'augmenter la demande;

5- les réserves actuelles sont suffisantes pour plusieurs années. A ceci, il faut ajouter le vanadium extrait des hydrocarbures qui peut être produit à des coûts moindres que celui obtenu conventionnellement.

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A la lumière de ces faits, l'exploitant du gisement du Canton de Rinfret, pauvre en vanadium, devra, s'il désire rentrer en production, créer son propre marché pour le vanadium, trouver des débouchés pour le fer et le titane contenus dans le minerai et utiliser un procédé économique pour concurrencer les autres producteurs.

Ainsi, nous recommandons de vérifier avec le Centre de recherches minérales s'il a réussi à trouver un procédé pour l'extraction du vanadium, condition nécessaire mais non suffisante pour que la mine de Rinfret puisse entrer en production. D'autre part, les crédits affectés au développement du gisement du ministère n'ont qu'une priorité très éloignée dans l'état actuel de la conjoncture pour ce métal.

Michel Bussière
Directeur du Bureau de Planification

CG/MB/lb

MINISTERE DES RICHESSES NATURELLES

LE MARCHE MONDIAL DU VANADIUM

Québec, le 28 septembre 1971.

Christian Leman
Bureau de Planification

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INTRODUCTION

Cette étude, dans sa première partie, donne une vue d'ensemble des aspects techniques du vanadium. Elle traite des procédés de traitement de minerais, énumère les produits les plus communs du vanadium et indique les usages de ces dits produits. Ainsi, elle nous permet de suivre le cheminement du minerai vanadifère jusqu'aux produits couramment utilisés dans l'industrie sidérurgique.

La seconde partie sur l'exploitation et l'industrie mondiale décrit, au moyen de cartes et tableaux, les activités des compagnies qui, en 1970, s'occupèrent de l'exploitation du minerai vanadifère.

Enfin, la dernière partie traite de chaque entreprise, des prix, des perspectives et des prévisions possibles de ce marché.

I EXTRACTION DU VANADIUM

Dans le passé, la récupération de l'anhydride vanadique (V_2O_5) de minerais vanadifères se faisait de la façon suivante: grillage du minerai ou du concentré avec du carbonate ou du chlorure de sodium pour produire du vanadate de sodium soluble à l'eau. Par précipitation, on obtenait de cette solution le métavanate d'ammonium (NH_2VO_3) et subséquemment l'anhydride vanadique.

Cependant, aujourd'hui les procédés de traitement des minerais vanadifères varient selon le type de dépôt en présence. Ainsi, nous examinerons sommairement ci-dessous les procédés de traitement des principaux minerais vanadifères présentement en exploitation.

(i) Dépôt d'uranium-vanadium

Les gisements de roscoélite (mica vanadifère) et de carnotite (un vanadate d'uranium et de potassium) du Colorado, du Nouveau-Mexique et de l'Utah ont été une des sources les plus constantes de vanadium, pour les Etats-Unis, au cours des dernières années.

Les procédés de traitement de ces minerais sont habituellement différents selon le type de gisements, même s'ils suivent le principe général suivant: le minerai, après avoir été moulu et tamisé, est mélangé avec des sels et grillé au four afin de convertir le vanadium en vanadate de sodium. Du vanadate de sodium lixivié à l'eau, on obtient le polyvanadate de sodium ("red cake") par précipitation avec de l'acide sulphurique. Ce précipité contient de l'uranium qui est extrait par lixiviation à l'acide et par filtration. On obtient ainsi le vanadate de sodium ("pure red cake") qui peut être vendu directement aux producteurs de ferro-vanadium afin d'en récupérer l'anhydride vanadique par fusion.

(ii) Dépôt de calcaire phosphatique

L'extraction du vanadium des roches phosphatées de l'Idaho aux Etats-Unis, contenant entre 0.2% à 0.3% de vanadium, consiste à faire fondre au four électrique les roches phosphatées en utilisant du carbone et de la silice. Le phosphate de calcium est ainsi réduit en phosphore par le carbone et en scorie de silicate de calcium, contenant le vanadium, par la réaction de la silice. Cette scorie qui contient approximativement 6% de vanadium est grillée afin d'en extraire le vanadium sous forme d'anhydride vanadique qui est expédié directement aux producteurs de ferro-vanadium.

(iii) Dépôt de magnétite titanifère

Depuis les quinze dernières années, la République de l'Afrique du Sud est devenue le plus important producteur mondial de vanadium. Les gisements exploités de magnétite titanifère, contenant jusqu'à 2.5% de pentoxide de vanadium (V_2O_5), sont tous situés dans le complexe géologique de Bushveld au Transvaal. Jusqu'à 1968, ce minerai était broyé et l'anhydride vanadique en était extrait par les procédés de grillage et de lixiviation à l'acide. A cette époque, ce minerai était traité uniquement pour le vanadium. Cependant, depuis 1968, une nouvelle usine, un complexe sidérurgique, construit par Anglo American Corp., récupère le vanadium comme co-produit du fer sous forme de scories de vanadium.

Lors de la construction du complexe sidérurgique, la présence du titane dans le minerai a empêché l'utilisation de haut fourneau pour extraire le fer. Il a donc fallu développer un procédé particulier. Ce procédé consiste à moudre le minerai, à le mélanger avec du carbone et du calcaire, puis l'introduire dans des fours rotatifs, utilisant comme combustible du charbon pulvérisé. Cette première étape de traitement réduit environ 35% du minerai. Cette fonte de fer pré-réduit est ensuite acheminée vers d'autres fours électriques où l'on obtient une réduction complète, c'est-à-dire, une fonte de fer contenant 1.4% de vanadium. La fonte est soufflée par l'oxygène à des températures contrôlées afin d'en extraire un scorie contenant 28% de V_2O_5. Ce produit qui est la dernière étape de transformation du minerai et expédié aux producteurs de ferro-vanadium.

II PRODUITS DU VANADIUM

Nous avons constaté sommairement dans le dernier chapitre les principaux procédés d'extraction du vanadium en fonction de divers minerais. On remarque que cette première étape de la transformation, toujours effectuée par le producteur minier, produit selon le cas un vanadate de sodium ("pure red cake") ou des scories de vanadium contenant jusqu'à 28% de V_2O_5. La seconde étape consiste à extraire de ces concentrés l'anhydride vanadique (V_2O_5) de qualité technique. Cette deuxième étape de la transformation du minerai peut s'effectuer au moulin même, c'est-à-dire par le producteur primaire de vanadium - c'est le cas des producteurs aux Etats-Unis - ou par les producteurs de ferro-alliages - c'est le cas des scories de vanadium produit par la République Sud Africaine, le Sud-Ouest Africain et l'Union Soviétique qui sont traités aux Etats-Unis, au Japon et dans les pays de l'Europe de l'Ouest.

L'anhydride vanadique de qualité technique, utilisée principalement pour la fabrication de ferro-vanadium, est le produit courant des producteurs primaires de vanadium ou des producteurs secondaires approvisionnés en concentrés de vanadium. On peut le trouver soit sous forme d'oxyde noir fondu, d'une teneur de 86% à 99% en V_2O_5, ou sous forme de poudre séchée à l'air contenant 83 à 86% de V_2O_5. La récupération de l'anhydride vanadique de ces concentrés ou scories s'effectue, en général, par les procédés de grillage aux sels et de lixiviation.

Par ailleurs, le ferro-vanadium utilisé dans l'industrie sidérurgique représente environ 80% de la consommation de vanadium. Il est consommé sous forme d'anhydride vanadique de qualité technique. Le tableau I ci-dessous donne ses caractéristiques requises pour la fabrication du ferro-vanadium:

Tableau 1

COMPOSITION TYPIQUE DE L'ANHYDRIDE VANADIQUE REQUIS POUR LA FABRICATION DE FERRO-VANADIUM

Composants	%
V_2O_5	99.1
Fe	0.20
SiO_2	0.40
Na_2	0.15
S	0.01
P	0.01
As	0.01

Source: Métal Bulletin, mai 1969.

On peut obtenir diverses catégories de ferro-vanadium dont la teneur en vanadium varie entre 35 à 85%, celle en carbone de 0.15 à 2% et celle en silicium de 0.50 à 11%. Le tableau 2 ci-dessous présente la composition des ferro-vanadium les plus communs.

Tableau 2

COMPOSITIONS TYPIQUES DES FERRO-VANADIUM
LES PLUS COMMUNS

Composants	Standard 80% V	Standard 50% V	Norvégien 50% V
	%	%	%
V	78-80	55-60	48-50
Al	1.0 max.	2.0 max.	trace
C	0.25 max.	0.15 max.	0.25 max.
Si	1.0 max.	1.5 max.	4.0 max.
P	0.05 max.	0.06 max.	-
S	0.10 max.	0.05 max.	-
As	0.08 max.	0.05 max.	-
Cr	-	-	4.5 max.
Mn	-	-	3.0 max.
Ti	-	-	0.5 max.

Source: Metal Bulletin, Mai 1969

Par ailleurs, au cours des dix dernières années les producteurs de ferro-vanadium américains ont développé des ferro-vanadium qui leur sont propres répondant d'une part, aux besoins de l'industrie de l'acier et d'autre part, à la nécessité de produire des ferro-vanadium moins coûteux. Ainsi, l'Union Carbide Corp. produit le CARVAN qui contient de 83 à 86% de vanadium, 10 à 13% de carbone et de 1 à 3% de fer et Foote Mineral Corp., le SOLVAN qui contient de 25 à 30% de vanadium, un maximum de 0.30% de carbone et un haut pourcentage en fer. Du fait de leur composition, ces deux produits ont des propriétés tant soit peu différentes. Le CARVAN, à cause de son contenu en carbone, n'est pas utilisé pour la fabrication d'acier à faible teneur en carbone. D'autre part, Foote Mineral Corp. a récemment mis sur le marché un nouveau ferro-vanadium, le FEROVAN, destiné aux aciers à faible alliage et de haute résistance.

Par ailleurs, on peut aussi obtenir de l'anhydride vanadique de catégorie chimique contenant 99.5, 99.7 et 99.94% de V_2O_5. Ces produits sont vendus à l'industrie des produits chimiques.

III USAGES DU VANADIUM

Les usages du vanadium sont nombreux et le tableau 3 ci-dessous montre la répartition des diverses applications aux Etats-Unis; les Etats-Unis qui est le seul pays offrant des statistiques de consommation. Néanmoins, on estime que la consommation des autres pays industrialisés suit la même tendance si ce n'est que l'industrie sidérurgique de ces pays est presque l'unique consommtrice de vanadium.

Tableau 3

REPARTITION DE LA CONSOMMATION DE VANADIUM
-ETATS-UNIS-
(en pourcentage)

	1965	1966	1967	1968	1969	1970[e]
Aciers	86	83	71	79	77	80
Alliages[1] (excluant les alliages d'acier)	7	10	12	9	10	11
Divers	7	7	17	12	13	9
TOTAUX	100	100	100	100	100	100

e: estimation
1: plus de 95% comprend des alliages à base de titane

On remarque que plus de 90% du vanadium est utilisé pour la fabrication de divers aciers et alliages à base de titane. De plus, on remarque sur le tableau 4 ci-dessous qu'aux Etats-Unis près de 80% du vanadium consommé est surtout utilisé sous forme de ferro-vanadium servant d'élément d'alliage dans l'industrie sidérurgique.

Tableau 4

CONSOMMATION DE VANADIUM AUX ETATS-UNIS
1965-1970
(tonnes courtes de vanadium)

	1965	1966	1967	1968	1969	1970[e]
Ferro-vanadium	4,042	4,511	4,305	4,712	5,193	4,250
Anhydride (V_2O_5)	127	198	153	155	113	108
Métavanadate d'ammonium	175	160	115	94	110	43
Autres[1]	364	612	672	534	739	612
TOTAUX	4,708	5,481	5,245	5,495	6,154	5,013

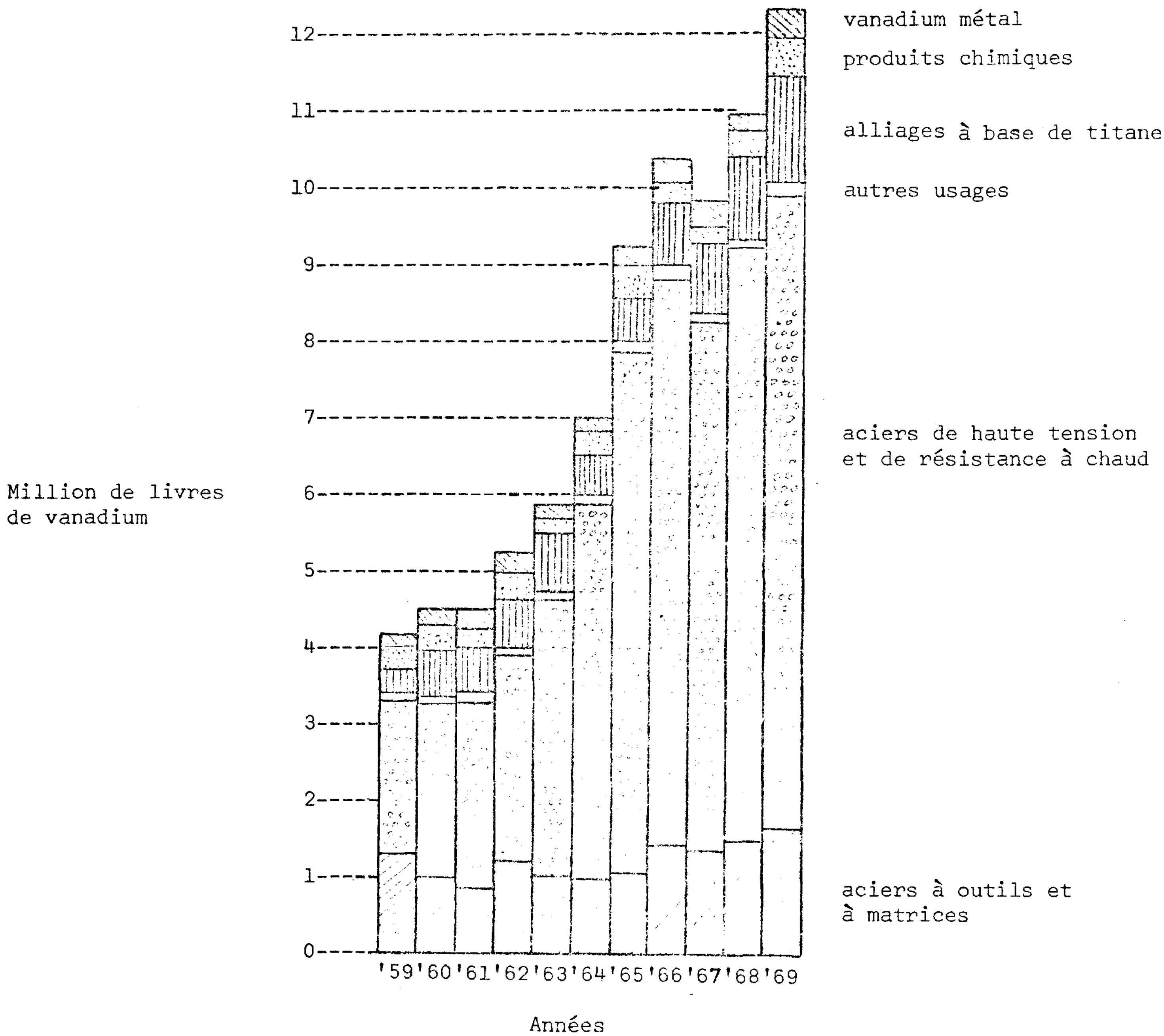
e: estimation
1: comprend principalement le vanadium comme V-Al alliage pour les alliages à base de titane

Source: Canadian Minerals Yearbook Preprints 1965-1970

D'autre part, le graphique no. I ci-après nous permet de constater (depuis 1959) le développement des usages du vanadium aux Etats-unis. On remarque ainsi une augmentation de la consommation du vanadium de l'ordre de 300% sur la période s'échelonnant entre 1959 et 1969. On note cependant que cette augmentation est presque uniquement due aux développements des usages du vanadium entrant dans la fabrication des alliages à base de titane et des aciers de haute tension et de résistance à chaud.

GRAPHIQUE I

CONSOMMATION DU VANADIUM SELON L'EMPLOI FINAL
1959-69
Etats-Unis



En se basant sur l'année 1969, on remarque qu'approximativement 80% du vanadium consommé aux Etats-Unis entre dans la fabrication des divers aciers. En ce qui concerne ce taux d'utilisation, on note cependant que les prévisions sont à la hausse. Ainsi, L.C. Bliss, Chairman de Foote Mineral Corp., prévoit que dans 15 ans l'acier sera responsable approximativement de 90% de la demande de vanadium; en comparaison avec 75% au cours de la dernière décennie. Ceci s'expliquera par la croissance de l'utilisation de l'acier à faible alliage et de haute tension comme acier de construction, de pipelines et à béton[1].

A ce stade de l'étude, on trouvera en Annexe 1 une brève analyse de l'industrie de ferro-alliages aux Etats-Unis qui fait ressortir l'importance du ferro-vanadium des autres ferro-alliages.

Par ailleurs, comme le souligne le tableau 5, les secteurs de consommation du vanadium sont nombreux.

1: Metals Weeks, November 16, 1970

Tableau 5

SECTEURS DE CONSOMMATION DU VANADIUM
ETATS-UNIS
-1968-
(tonnes courtes de vanadium)

Emploi final	Acier	Alliages non-ferreux	Produits chimiques et céramiques	Fonte	Autres	Totaux
Matériaux de construction	3,030	-	-	10	-	3,040
Machines et équipements de construction	850	-	-	10	-	860
Equipements de transport	480	540	-	25	-	1,045
Machines de travail sur métaux et outils	530	10	-	25	5	570
Produits chimiques	-	-	190	-	-	190
Autres usages	-	-	-	-	65	65
TOTAUX	4,890	550	190	70	70	5,770

Source: Mineral Facts and Problems, U.S. Bureau of Mines, 1970 Ed.

D'après le tableau 5, les aciers au vanadium sont surtout utilisés pour la fabrication de matériaux de construction. L'utilisation des aciers au vanadium dans ce secteur s'explique par le fait que ces aciers possèdent des limites d'élasticité élevées, qualités requises dans les charpentes métalliques d'édifices, de ponts, etc... Un autre facteur, responsable du développement de la consommation du vanadium, est l'augmentation de la construction de pipelines. Le tableau 6 donne l'évolution de la production d'acier à pipeline et d'acier de construction aux Etats-Unis de 1961 à 1969. Le développement du marché du vanadium étant directement lié à la croissance de la construction de pipelines tout développement dans ce secteur augmente par le fait même le marché du vanadium.

Tableau 6

PRODUCTION D'ACIER A FAIBLE ALLIAGE
ET DE HAUTE TENSION
-ETATS-UNIS-
(milliers de tonne)

Année	Production d'acier de construction	Expéditions d'acier de pipeline
1961	903	5
1962	1,040	141
1963	1,432	211
1964	1,584	493
1965	2,056	697
1966	2,002	1,012
1967	2,247	931
1968	2,786	1,129
1969	2,850	1,050

Source: Mining & Engineering Journal, March 1970

L'utilisation du vanadium pour la fabrication d'équipement de transport est aussi importante; en 1968, approximativement 18% de la consommation totale des Etats-Unis. Ceci est lié au fait que d'une part, le vanadium donne aux alliages à base de titane utilisés dans l'industrie aéronautique une haute résistance aux températures élevées et d'autre part, que les aciers au vanadium de haute résistance sont utilisés pour la fabrication de pièces motrices d'équipement de transport.

Enfin, les composés du vanadium servent, dans l'industrie chimique, de catalyseurs dans la production d'acide sulfurique et le craquage catalytique de produits pétroliers. L'industrie s'en sert également comme colorant du verre, comme élément de vitrification des articles de céramique; il entre aussi dans les tiges à sonder et dans les matériaux résistant à l'usure et servant à la fabrication d'outils de coupe[2].

2: Annuaire des Minéraux du Canada

IV EVOLUTION DE LA PRODUCTION MONDIALE

Le tableau 7 ci-dessous extrait des Annales des Mines de janvier 1971 donne la production minière mondiale de vanadium (exception faite des pays du bloc communiste) pour 1968 en valeur, et en tonne courte de vanadium contenu sous forme d'anhydride vanadique (V_2O_5) ou de concentrés. On remarque la valeur restreinte de la production minière mondiale ($44.9 millions), la dispersion des pays producteurs sur trois continents ainsi que la prédominance des Etats-Unis sur ce marché qui ont produit en 1968 (6,470 t.c.) près de 52% de la production mondiale.

Tableau 7

PRODUCTION MINIERE MONDIALE DE VANADIUM
-1968-

Pays	Production en tonne courte de métal contenu	Valeur globale en 10^6 $
Etats-Unis	6,470	23.1
Afrique du Sud (Rep.)	2,492	8.7
Sud-Ouest Africain	1,320	4.7
Finlande	1,317	4.7
Norvège	935	3.3
Autres pays	116	.4
TOTAL	12,650	44.9
Chiffres * 1963	9,350	24.7
Chiffres * 1950	1,684	2.2

* Les chiffres correspondants pour 1963 et 1950 sont rappelés après avoir été transformés en dollars 1968.

Par ailleurs, le tableau 8 donne la production en tonne courte de vanadium par pays producteurs pour les années 1955, 1960, 1965 et 1970. Au sujet de l'évolution de la production mondiale de vanadium, on constate, en valeur absolue et en pourcentage, l'augmentation de production suivante:

- de 1950 à 1955: +2,312 t.c. ou 137%
- de 1955 à 1960: +3,240 t.c. ou 81%
- de 1960 à 1965: +2,598 t.c. ou 35%
- de 1965 à 1970: +2,166 t.c. ou 22%

Tableau 8

PRODUCTION MONDIALE DE VANADIUM
EN MINERAIS ET CONCENTRES
(tonnes courtes de vanadium)

Pays	1955	1960	1965	1970[e]
Etats-Unis	3,286	4,971	5,226	6,000
Afrique du Sud[1] (Rep.)	-	656	1,519	3,000
Sud-Ouest Africain	632	838	1,275	700
Finlande	-	625	1,063	1,400
Norvège	-	-	750	900
Autres pays	78	146	1	-
TOTAL	3,996	7,236	9,834	12,000

e: estimation
1: vanadium contenu dans l'anhydride vanadique V_2O_5; ne comprend pas le vanadium obtenu du traitment de scories, production qui a débutée en 1968
Source: U.S. Bureau of MInes, Minerals Yearbooks

Tableau 9

Tableau de comparaison des tonnages

Substance	Unité	1968	1963	1950	$\frac{1968}{1963} \times 100$	$\frac{1968}{1950} \times 100$
Pétrole	10^6 t	1 922,3	1 303,6	522,8	147	368
Houille	10^6 t	2 051,7	1 928,0	1 457,8	106	141
Gaz naturel	10^9 m^3	837,9	569,9	205,6	147	408
Cuivre	10^3 t	5 400,0	4 755,0	2 530,0	114	213
Fer	10^6 t	374,6	274,1	121,9	137	307
Lignite	10^6 t	745,6	720,3	340,2	104	219
Or	t	1 438,5	1 364,0	877,1	105	164
Produits condensables du gaz naturel	10^6 t	71,0	53,1	24,8	134	286
Sel	10^6 t	127,6	94,8	48,0	135	266
Soufre	10^6 t	18,5	12,4	5,8	149	319
Zinc	10^3 t	5 020,0	3 670,0	2 227,0	137	225
Phosphates	10^6 t	59,5	36,9	16,0	161	372
Nickel	10^3 t	549,1	364,3	140,9	151	390
Plomb	10^3 t	3 010,0	2 550,0	1 705,9	118	176
Étain	10^3 t	228,9	192,4	181,0	119	126
Argent	t	8 587,5	7 780,0	5 660,0	110	152
Diamants	10^6 ct	(41,9)	(30,7)	(15,3)	(136)	(274)
Potasse	10^6 t	15,5	10,8	4,6	141	337
Amiante	10^3 t	4 300,0	2 900,0	1 205,8	148	357
Uranium	10^3 t	25,1	31,0	—	81	—
Platine	t	106,9	48,2	18,8	222	569
Bauxite	10^6 t	48,8	30,6	8,3	159	588
Manganèse	10^3 t	8 180,0	6 470,0	3 200,4	126	256
Kaolin	10^3 t	11 500,0	9 000,0	3 860,0	128	298
Molybdène	10^3 t	65,8	41,3	14,6	159	451
Pyrite	10^3 t	10 350,0	9 100,0	4 176,0	114	248
Tungstène	10^3 t	40,5	34,8	14,6	116	227
Mercure	t	8 950,0	8 260,0	4 671,8	108	192
Borate	10^3 t	1 360,0	915,0	610,0	149	230
Talc	10^3 t	4 500,0	3 050,0	1 250,7	148	260
Spath-Fluor	10^3 t	3 600,0	2 150	837,2	167	430
Magnésite	10^3 t	11 110,0	8 200	2 150,0	135	517
Chromite	10^3 t	2 320,0	1 820	1 049,0	127	221
Bentonite	10^3 t	(3 900,0)	(2 570,0)	—	(152)	—
Barytine	10^3 t	3 690,0	2 950,0	1 712,0	125	215
Ilménite	10^3 t	1 670,0	1 103,0	460,0	151	363
Carbonates naturels	10^3 t	1 972,4	1 151,0	395,0	171	499
Vanadium	t	11 500,0	8 500,0	1 531,0	135	751
Mica	10^3 t	(194,0)	(168,0)	(81,0)	(115)	(240)
Cobalt	10^3 t	20,2	16,2	7,1	125	285
Antimoine	10^3 t	62,2	57,0	48,7	109	128
Sulfate de sodium	10^3 t	1 560,0	1 020,0	600,0	153	260
Rutile	10^3 t	310	202	25,3	153	1 225
Feldspath	10^3 t	2 300,0	1 740,0	782,0	132	294
Nitrates	10^3 t	678,9	1 136	1 614,4	60	42
Asphaltes naturels	10^3 t	800,0	650,0	252,9	123	316
Graphite	10^3 t	(470,0)	(710,0)	(131,0)	(66)	(359)
Zircon	10^3 t	370,0	240,0	42,0	154	881
Colombo-tantalite	10^3 t	(9,1)	(4,3)	—	(212)	—
Cyanite	10^3 t	(190,0)	(154,1)	—	(124)	—
Calcaires asphaltiques	10^3 t	2 000,0	1 740,0	1 819,4	115	110
Cryolithe	10^3 t	67,5	67,1	44,8	101	151
Béryl	t	6 800,0	5 080,0	6 640,0	134	102
Augmentation moyenne calculée sur les 15 premières substances					129,5	245

Nota. — Nous avons mis des tonnages et calculé des rapports pour toutes les substances, mais nous sommes parfaitement conscients que pour certaines d'entre elles la signification de ces chiffres (et surtout les rapports) est très sujette à caution, c'est pourquoi nous les avons mis entre parenthèses.

Les tableaux 9 "Comparaison de production des tonnages" et 10 "Taux de progression des substances en 1968 par rapport à 1963" indiquent l'évolution mondiale de la production du vanadium par rapport aux autres substances minérales.

Tableau 10

TAUX DE PROGRESSION DES SUBSTANCES EN 1968 PAR RAPPORT A 1963

	Progression en %	Taux moyen annuel en %
Par rapport à 1963		
Platine	+122	17.3
Carbonates naturels	+ 71	11.3
Spath-fluor	+ 67	10.8
Phosphates	+ 61	10.0
Bauxite	+ 59	9.7
Molybdène	+ 59	9.7
Zircon	+ 54	9.0
Sulfates naturels	+ 53	8.9
Rutile	+ 53	8.9
Ilménite	+ 51	8.6
Nickel	+ 51	8.6
Soufre	+ 49	8.3
Borate	+ 49	8.3
Talc	+ 48	8.2
Pétrole	+ 47	8.0
Gaz naturel	+ 47	8.0
Vanadium	+ 35	7.0
Indices en volume:		
Substances non métalliques	+ 42	7.3
Produits énergétiques	+ 31	5.5.
Minerais métalliques	+ 22	4.1
Tous minerais	+ 29	5.2

Source: Annales des Mines, Janvier 1971

On constate que pour 1968, par rapport à 1963, la production du vanadium a progressé de 35% à un taux annuel moyen de 7%. Quoique n'étant pas le plus élevé, ce taux est néanmoins supérieur à la moyenne annuelle de 4.1% pour l'ensemble des substances métalliques.

En résumé, la production de vanadium qui a débuté au début du siècle avec la mise en exploitation des gisements péruvien et du Sud-Ouest Africain a connu son développement et son plein essor à partir des années 50 avec la mise en exploitation des gisements d'uranium-vanadium de l'Utah et du Nouveau-Mexique des Etats-Unis. Ainsi, de 1950 à 1960, une forte augmentation de la production mondiale (+5,552 tonnes courtes ou 330%) s'est fait sentir à la suite d'une production accrue des Etats-Unis et du Sud-Ouest Africain et de la mise en exploitation des gisements de magnétite titanifère et vanadifère de la Finlande et de la République Sud-Africaine. De 1960 à 1970, l'augmentation de 4,764 tonnes courtes de vanadium (65%) est liée à l'augmentation de la capacité de production des pays mentionnés ci-dessus et à la mise en exploitation de gisements de magnétite Ti-V en Norvège. On note, cependant, que le vanadium contenu dans la production de scories de la République Sud Africaine n'est pas inclus dans les statistiques mentionnées ci-dessus. La production qui a débuté en 1968 aurait mis sur le marché mondial, en 1970, l'équivalent de 6,000 tonnes courtes de vanadium soit près d'un tiers (1/3) de la production mondiale.

V LA PRODUCTION PAR PAYS

Au tableau 11 ainsi qu'au tableau graphique II ci-joints, on indique par pays l'évolution de la production minière de vanadium de 1955 à 1970.

Par période de cinq ans, les pays producteurs de vanadium enregistrent, en valeur absolue, les variations suivantes:

- de 1955 à 1960:	Etats-Unis	+1,685
	République Sud Africaine	+ 656
	Sud-Ouest Africain	+ 206
	Finlande	+ 625
	Norvège	-
- de 1960 à 1965:	Etats-Unis	+ 255
	République Sud Africaine	+ 863
	Sud-Ouest Africain	+ 437
	Finlande	+ 438
	Norvège	+ 750
- de 1965 à 1970:	Etats-Unis	+ 774
	République Sud Africaine	+1,481
	Sud-Ouest Africain	- 575
	Finlande	+ 337
	Norvège	+ 150

On retire, des variations mentionnées ci-dessus, les observations suivantes:

1. Les Etats-Unis ont connu, de 1950 à 1955, une forte augmentation (+51%) de la production s'estompant de 1960 à 1965 (+5%) et reprenant de 1965 à 1970 (+15%), mais avec moins de vigueur qu'au cours de 1955 à 1960.

2. La production de la République de l'Afrique du Sud a augmenté considérablement depuis sa première année de production en 1957. Ainsi, de 1960 à 1965, elle s'est majorée de +132%, et de 1965 à 1970, plus de 98%. Cependant, si l'on inclut la production de vanadium contenue dans les scories, produit par Highveld Steel & Vanadium Corp., on constate que ce pays a présentement une production supérieure à celle des Etats-Unis.

3. La production de vanadium du Sud-Ouest Africain a progressé de plus de 33% de 1955 à 1960 et de plus de 52% de 1960 à 1965. De 1965 à 1970, on note une baisse de 45%. Cette baisse provient de la diminution de la teneur du vanadium, contenue dans les concentrés de plomb-zinc.

4. La Finlande et la Norvège ont connu des hausses de production continues depuis leur première année de production en 1956 et 1964 respectivement.

On remarque les faits suivants concernant les principaux pays producteurs:

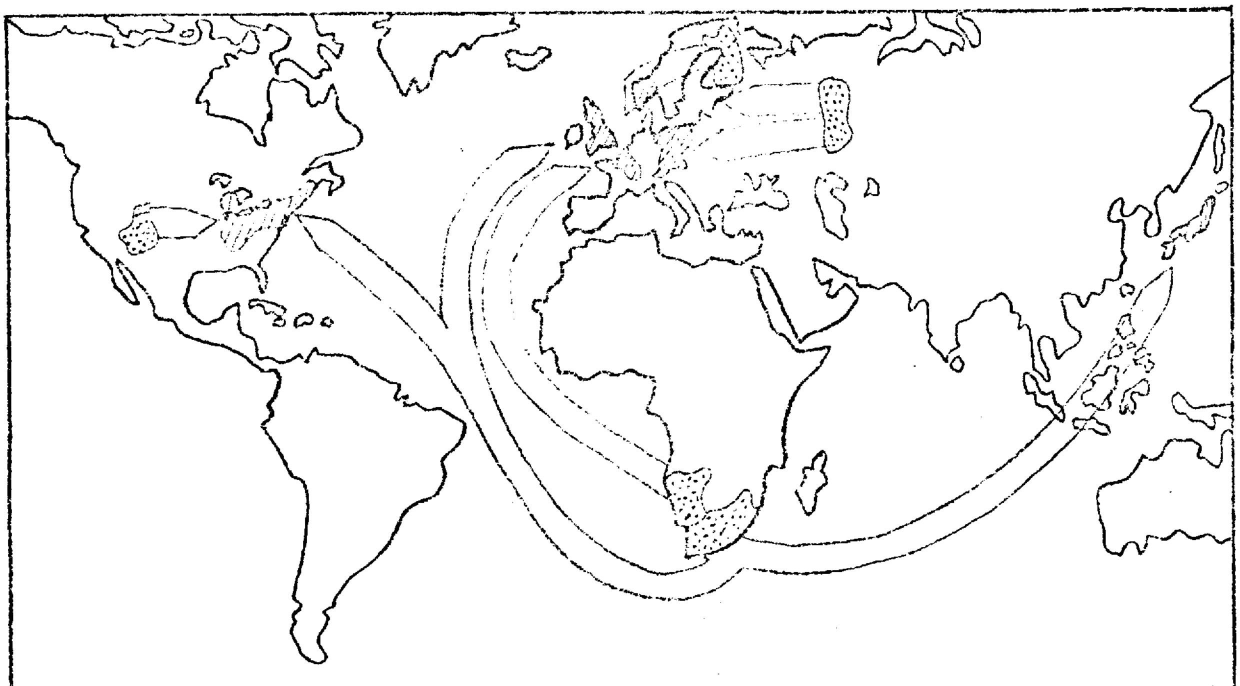
- les Etats-Unis sont, en 1970, le deuxième producteur mondial à la suite de l'entrée en production de Highveld Steel & Vanadium Corp. de l'Afrique du Sud. De ce fait, depuis quelques années la production américaine de vanadium tend à stagner tandis que les importations de scories de vanadium augmentent;

- la République de l'Afrique du Sud est le premier producteur mondial à la suite de la production de scories par Highveld Steel & Vanadium Corp. Cette société produit l'équivalent de 6,000 tonnes courtes de vanadium par an soit le tiers de la production mondiale, estimée en 1970 à 18,000 tonnes courtes de vanadium. Ainsi, la République Sud Africaine détient un potentiel de production de 9,000 tonnes courtes par an, soit la moitié de la production mondiale;

- l'Union Soviétique tend à devenir un fournisseur important de scories de vanadium particulièrement pour l'Europe de l'Ouest. Ainsi, en 1968, on estime les exportations de scories de l'Union Soviétique à destination de l'Europe de l'Ouest équivalente à 6 millions de livre de vanadium, soit près de 35% de la consommation européenne.

On considère, ci-après, les producteurs par pays (voir la Carte no. 1 "Acheminement du vanadium vers ses marchés" et les tableaux 12 et 13 qui donnent les statistiques pertinentes des producteurs mondiaux).

CARTE 1



Acheminement du vanadium vers ses marchés

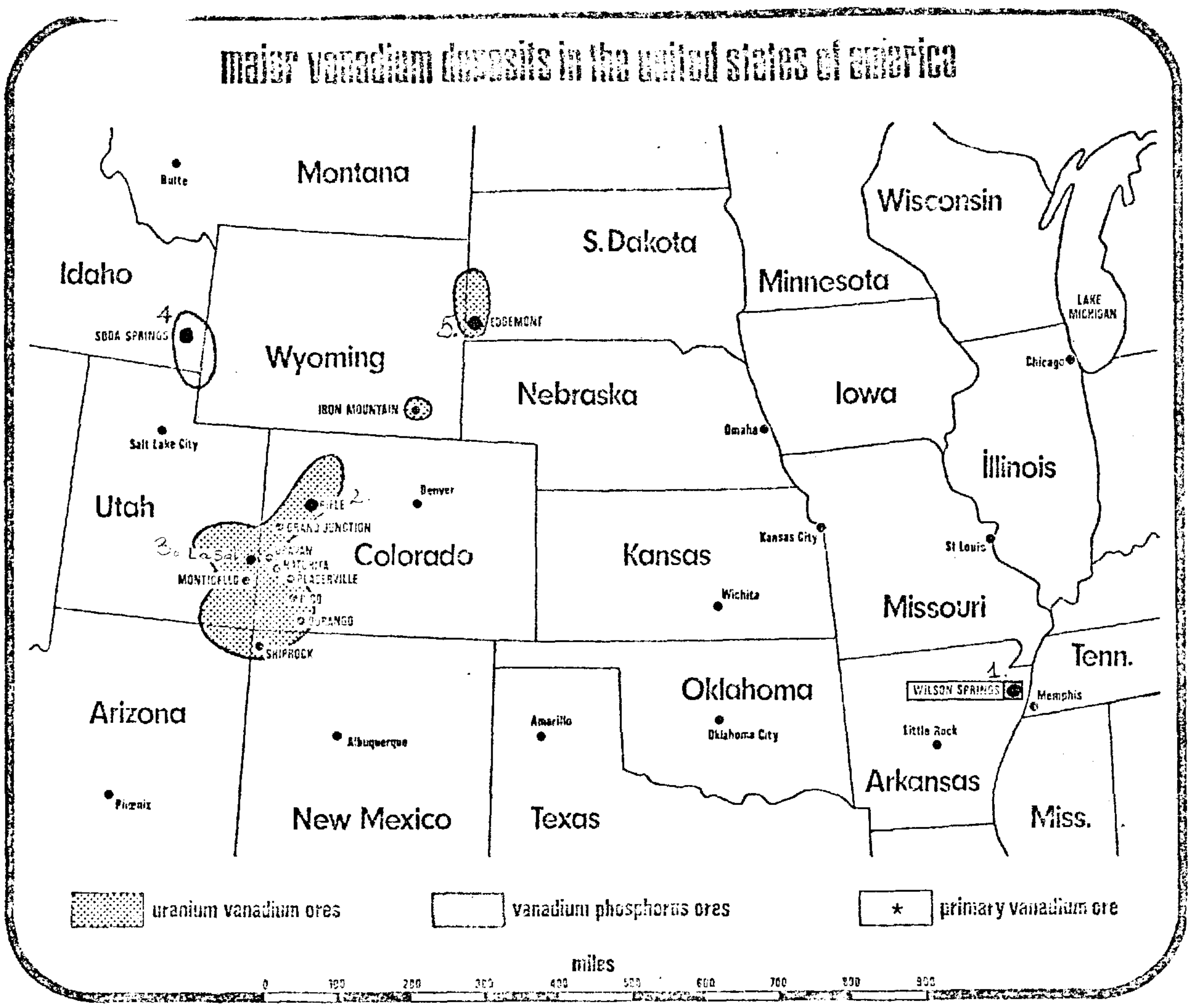
pays avec minerai de V

régions qui utilise le V

(i) Les Etats-Unis

Aux Etats-Unis, le vanadium est actuellement récupéré comme sous-produits de l'uranium, du phosphore obtenu du traitement de roche phosphatée et comme produit primaire du complexe d'extraction et de broyage de l'Union Carbide Corporation à Wilson Spring, Arkansas. La carte No. 2 ci-dessus indique l'endroit et le type de dépôts miniers exploités présentement aux Etats-Unis ainsi que le nom des sociétés exploitantes.

CARTE No 2



Friday, May 23, 1969 Metal Bulletin

1., 2. et 3. Union Carbide Corporation (UCC)
4. Kerr-McGee Chemical Corporation
5. Susquehanna Western Corporation

On constate qu'aux Etats-Unis, trois sociétés, Union Carbide Corporation, Kerr-McGee Corporation et Susquehanna Western Corporation, récupérent du vanadium de gisements miniers. On note d'autre part, qu'à l'exception de Kerr-McGee Corporation, les deux autres sociétés fabriquent du ferro-vanadium, c'est-à-dire qu'elles consomment en tout ou en partie leur production minière sous forme d'anhydride vanadique (V_2O_5).

1. Union Carbide Corporation (UCC)

Union Carbide Corporation est la plus importante des sociétés américaines productrices de ferro-alliages. Cette société produit presque toute la gamme des ferro-alliages, c'est-à-dire, les ferro-alliages de manganèse, de titane, de chrome, etc...et de vanadium.

Par ailleurs, UCC est aussi le plus important producteur de vanadium aux Etats-Unis. Le "Mining and Metals Division" de l'UCC extrait du vanadium de trois gisements: deux sont des gisements d'uranium-vanadium situé à LaSal dans l'Utah et à Rifle au Colorado et l'autre est un dépôt primaire de vanadium situé à Wilson Spring en Arkansas. Le dépôt de Wilson Spring, de loin le plus importsnt aux Etats-Unis, a une capacité de production de 10 millions de livres de V_2O_5 par an. On estime les réserves de ce gisement à 30,000 tonnes de vanadium contenu dans un minerai d'une teneur de .56% vanadium. Les deux autres dépôts d'uranium-vanadium possèdent des réserves possibles de 40,000 tonnes de vanadium titrant entre 1.25% à 2.0% de V_2O_5.

L'anhydride vanadique produit à Wilson Spring et à Rifle est expédié à l'usine de Marietta en Ohio pour produire du ferro-vanadium et du CARVAN. Ainsi, l'Union Carbide consomme toute sa production d'anhydride vanadique destinée à la fabrication de ferro-vanadium. Cette société vend elle-même ses produits.

En résumé, on constate que l'Union Carbide Corporation est une société verticalement intégrée s'occupant de l'extraction, de la transformation des produits miniers et de la commercialisation des dits produits. On remarque aussi la présence d'une filiale de l'UCC, Ucar Mineraly, en République Sud Africaine à Britts au Transvoal, qui produit du CARVAN à destination du Japon.

2. Kerr-McGee Chemical Corp.

Comme on peut le constater sur la carte No. 2 Kerr-McGee récupère à Soda Spring, Idaho de l'anhydride vanadique comme sous-produit du traitement de roches phosphatées. A partir d'un minerai de roches phosphatées titrant 0.2% à 0.3% de vanadium, Kerr-McGee obtient, par un procédé de "fusion au four électrique", un scories contenant approximativement 6% de vanadium. Ce procédé de fusion employé à la fabrication de phosphore élémentaire pour les phosphates industriels et chimiques, consiste à faire fondre ces roches phosphatées, du carbone et de la silice. Outre le phosphore élémentaire récupéré par condensation, une scorie de silicate de calcium contenant 6% de vanadium est obtenue. Il suffit de griller ces scories pour obtenir l'anhydride vanadique.

Cependant, Kerr-McGee ne produit par de ferro-vanadium. Toute sa production est vendue à des producteurs de ferro-vanadium sur le marché métallurgique américain.

3. Susquehanna Western Corporation

A son usine de Edgemont dans la Dakota Sud, Susquehanna Western Inc. récupère de l'anhydride vanadique du traitement de minerais d'uranium-vanadium. Cette société produit actuellement du ferro-vanadium à partir de sa propre production et des importations de scories provenant de l'Union Soviétique(1).

(1) Metals Week, 29 mars 1971.

Cependant, Susquehanna Western ne consomme qu'une partie de sa production d'anhydride vanadique. Elle vend le reste sur le marché métallurgique américain.

En conclusion, on constate que les trois sociétés (Union Carbide, Kerr-McGee et Susquehanna Western) récupèrent l'oxyde de vanadium en traitant du minerai local. Cependant, à l'exception du gisement primaire de l'UCC à Wilson Spring, on note que ces trois sociétés récupèrent le V_2O_5 comme sous-produit - Union Carbide et Susquehanna Western de leur production d'uranium et Kerr-McGee de sa production de phosphore. Union Carbide, le plus important producteur, consomme toute sa production d'oxyde en fabriquant du ferro-vanadium. Susquehanna Western pour sa part, utilise une partie de son oxyde de vanadium pour produire du ferro-vanadium et vend l'autre partie de sa production aux producteurs de ferro-vanadium. Enfin, Kerr-McGee vend son entière production d'oxyde de vanadium aux producteurs de ferro-vanadium (1).

(1) Voir tableau 14 "Producteurs de ferro-vanadium aux Etats-Unis".

TABLEAU 14

PRODUCTEURS DE FERRO-VANADIUM

ETATS-UNIS

- 1971 -

SOCIETES	SOURCES D'APPROVISIONNEMENT EN MINERAIS CONCENTRES OU OXYDES
Union Carbide Corporation	- oxyde de vanadium obtenu du traitement de minerais de ses propres gisements, à Wilson Spring, Arkensas, LaSal, Utah et Riffle, Colorado.
Foote Mineral Corporation	- oxyde de vanadium obtenu du traitement de scories de Highveld & vanadium corporation de la République de l'Afrique du Sud.
Reading Alloy Shieldalloy Corporation Metada Metals & Chemicals	- oxyde de vanadium obtenu du marché métallurgique. (Voir annexe II).
Susquehanna Western Inc.	- oxyde de vanadium obtenu du traitement de scories en provenance de l'Union Soviétique et de minerais de son propre gisement à Edgemont, S. Dakota.

(ii) La République de l'Afrique du Sud

La production du vanadium de la République de l'Afrique du Sud a débuté en 1957 avec l'entrée en production de Minerals Engineering Co. (Ltd.), S.A. qui récupérait de l'anhydride vanadique du traitement chimique de la magnétite Ti-V. Cette société fut achetée en 1960 par Anglo-American Corp. qui opéra sous le nom de la Transvaal Vanadium Co. Mais ce n'est qu'en 1966, lors de la création par Anglo-American Corp. de la Highveld Steel & Vanadium Corp. que la Transvaal devint la Vantra Division de Highveld. Cependant, ce n'est qu'en 1969 que Highveld Steel & Vanadium Corp. proprement dit, devait débuter ses opérations.

Entre temps, une filiale de l'Union Carbide Corp. des Etats-Unis, Ucar Minerals Corp., s'implanta dans ce pays pour produire de l'anhydride vanadique et récemment du CARVAN.

2.

En République de l'Afrique du Sud, il y a donc trois sociétés productrices de ferro-vanadium soit Highveld Steel & Vanadium Corp. et Ucar Minerals. Vantra Division de Highveld

<u>Highveld Stell & Vanadium Corp.</u>

Quoique Highveld Steel & Vanadium Corp. ait débuté ses opérations en 1969, la compagnie mère, Anglo American Corp. of South Africa avait en 1959 déjà l'intention d'exploiter ces gisements de magnétite titanifère et vanadifère. Ainsi, en 1961, la compagnie a commencé un programme d'exploration géologique d'une durée de trois ans. Il permit de découvrir 200 millions de tonnes de réserves exploitables à ciel ouvert. A la suite des études de marché mondial qui se concluèrent par la signature de contrats de vente de scories de vanadium avec Vanadium Corp. of America, maintenant Foote Mineral, Anglo-American Corp. décidé, en 1964, de mettre en chantier la construction d'un complexe intégré de fer, d'acier et de scories de vanadium.

Il est à noter que ce complexe sidérurgique de Highveld Stell & Vanadium Corp. est le seul dans le monde qui sont basé sur la rentabilité de deux produits, le fer et le vanadium. La réalisation du projet a duré cinq ans et la production a débuté en avril 1969. (Voir en annexe III, l'article du Steel Times de juin 1970 sur le projet Highveld Steel & Vanadium Corp.).

La capacité de production de Highveld est actuellement la suivante:

- 420,000 tonnes d'acier;
- 23,000,000 lbs. de V_2O_5 du traitement de scories contenant 25% de V_2O_5.

Highveld a cependant été conçue de telle sorte que sa capacité de production puisse être facilement augmentée. Ainsi, la société prévoit déjà pour 1972, une augmentation de sa production. Les scories de vanadium sont expédiées vers les Etats-Unis (Foote Mineral Corp.), le Japon (Awamura Metal Industry Co. Ltd., Nippon Denko) et l'Angleterre.

Les autres producteurs de vanadium sont Ucar Minerals,filiale de l'Union Carbide au U.S.A., et la Vantra Division de Highweld, filiale de l'Anglo American Corp. on South Africa. Ces deux sociétés possèdent une capacité de production annuelle de 3,000 tonnes de vanadium.

La Vantra Division produit environ 7 millions de livres de V_2O_5 par an destinées aux producteurs de ferro-vanadium du Japon, de l'Autriche et de l'Angleterre. Ucar Minerals produit approximativement 3 millions de livres par an. Cependant, Ucar Minerals pourra dorénavant consommer sa production puisqu'elle produit du CARVAN. On remarque que ces deux sociétés récupèrent le V_2O_5 par le traitement chimique de la magnétite titanifère-vanadifère du complexe de Bushveld.

En conclusion, on constate que la République Sud Africaine est le premier producteur mondial de vanadium dont le potentiel de production de scories et d'anhydride vanadique s'élève à environ 9,000 tonnes de vanadium par an. La situation privilégiée de ce pays provient certainement du fait qu'il détient des réserves presque inépuisables de magnétite titanifère et vanadifère et que ses gisements soient exploités par deux firmes multinationales, verticalement et horizontalement intégrées.

(iii) Autres pays

Dans les chapitres précédents, on constate que les Etats-Unis et la République Sud Africaine produisent près de 75% de la production mondiale de vanadium en minerai, concentré et oxyde. Examinons maintenant l'importance des autres pays producteurs: la Finlande, la Norvège et le Sud-Ouest Africain.

On constate premièrement que ces pays ont traditionnellement alimenté le marché européen. En effet, depuis et avant 1930, le Sud-Ouest Africain approvisionne ce marché en concentrés de vanadate de plomb, la Finlande, depuis 1956, en oxyde de vanadium et la Norvège, depuis 1965, en ferro-vanadium et en fonte de titane-vanadium. En 1970, on estime la production équivalente de vanadium de la Finlande, de la Norvège et du Sud-Ouest Africain à 1,400, 900 et 700 tonnes respectivement.

1. La Finlande

La production finlandaise de vanadium sous forme d'anhydride vanadique provient de la Otanmäki Co. qui fut almalgamée en 1968 avec la sidérurgie d'Etat, la Rautarraukki Co.

La Rautarrukki Co. exploite le gisement de magnétite-Ti-V de l'Otanmäki et produit des boulettes de fer, un concentré d'ilménite et de l'anhydride vanadique. Le procédé de traitement du concentré de magnétite est relativement classique (grillage au sels et lixiviation. Il permet d'obtenir des boulettes de fer et de l'anhydride vanadique. La production de boulettes est expédiée au complexe sidérurgique de Rautarrukki, celle du concentré d'ilménite à la Vuorikemia Co. alors que celle de l'anhydride vanadique est vendue aux producteurs européens de ferro-vanadium. La capacité de production de V_2O_5 est estimée à 3,000 tonnes par an. Les réserves s'évaluent à 50 millions de tonnes, contenant 35% Fe, 12 à 15% TiO_2 et 0.3% V.

On remarque donc que l'exploitation du gisement de magnétite titanifère et vanadifère dépend de l'activité des deux compagnies d'Etat, la sidérurgie Rautarrukki et la compagnie Vuorikemia. Cette dernière n'est intéressée qu'au concentré d'ilménite. On peut conclure que le gisement Otanmäki ne serait pas rentable si on n'avait exploité que le vanadium. De plus, la société Rautarrukki n'étant pas une société de ferro-alliage vend sa production de V_2O_5 aux producteurs européens de ferro-vanadium.

2. La Norvège

La production norvégienne de vanadium provient de la société intégrée Christiana Spigeverk. Elle possède une acierie à Oslo et des installations de production de ferro-alliage et de fonte à Svélgen. Ainsi, la division Bremanger Smelteverk de Christiana Spigerverk produit et vend du ferro-vanadium 45-55% V, de la scories de vanadium et de la fonte de titane-vanadium. L'approvisionnement en minerai de vanadium est assuré par la mine

Rodsand qui produit approximativement 200,000 tonnes de concentrés de magnétite par an contenant environ 63% de fer et 0.5% V. en 1970, la production norvégienne de vanadium s'élève à 900 tonnes.

3. Le Sud-Ouest Africain

Le vanadium Sud-Ouest Africain est extrait comme sous-produit du concentré de plomb produit par la compagnie South-West Africa Co. Ltd. (SWAC) de la mine Berg Aukas. Par ailleurs, outre les concentrés de plomb-vanadium, la SWAC produit aussi des concentrés de plomb, de zinc et de tungstène-étain aux mines de Berg-Aukas et Brandberg West. Ainsi, au cours de l'année financière se terminant le 30 juin 1970, la SWAC a exporté en Europe, 4,274 tonnes de concentrés de plomb-vanadifère, titrant environ 17% de V_2O_5. Les réserves de la mine Berg Aukas étaient estimées à la fin 1968 à 1.8 million de tonnes de minerais, titrant 5% Pb, 24% Zn et 0.7% V_2O_5. En 1970, la SWACO a produit l'équivalent de 700 tonnes de vanadium. Cette production est inférieure à celle des années précédentes. Cependant, on prévoit au cours des prochaines années une augmentation de la production de vanadium. En effet, une nouvelle section de la mine Berg Aukas ayant des teneurs plus élevées en vanadium, est entrée en exploitation (1).

(1) Mining Annual Review, June 1971.

VI LES PRIX

Le tableau 15 et le graphique III donnent les variations du prix de l'anhydride vanadique de qualité technique[1], basées sur le prix de détail à l'exportation, aux Etats-Unis de 1965 à 1971.

Tableau 15

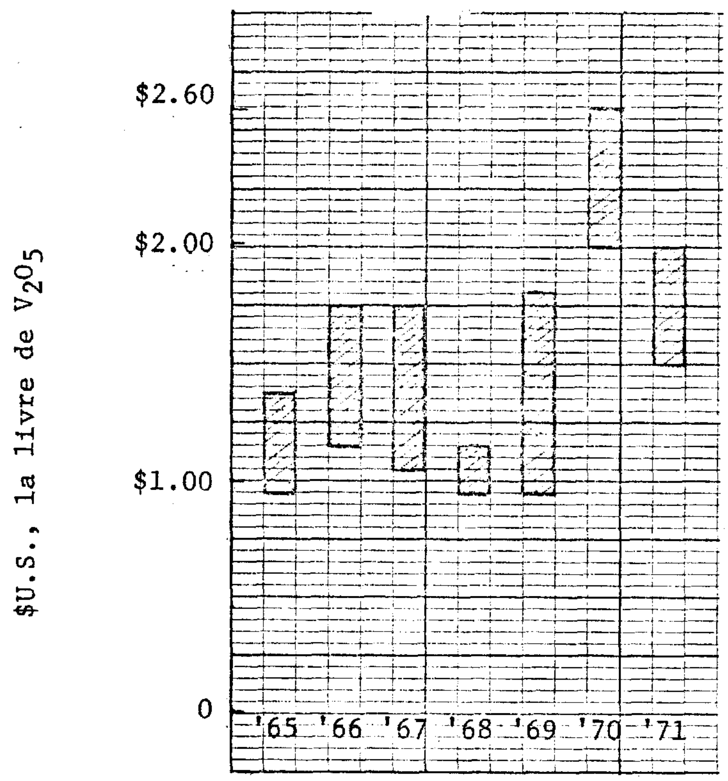
ANHYDRIDE VANADIQUE
\$U.S. la livre de V_2O_5

1965	1966	1967	1968	1969	1970	1971
\$0.95- 1.38	\$1.15- 1.75	\$1.05 1.75	\$1.15 0.95	\$1.80 0.95	\$2.60 2.00	\$2.00 1.50

1: à noter que l'anhydride vanadique de qualité technique se vend à la livre de V_2O_5 (pentoxyde de vanadium) contenu, tandis que le ferro-vanadium, à la livre de vanadium.

GRAPHIQUE III

ANHYDRIDE VANADIQUE
$U.S. la livre de V_2O_5



Exception faite de l'année 1968, on constate que de 1965 à 1970 la tendance des prix du vanadium était à la hausse, atteignant $2.60 US la livre de V_2O_5 en juin 1970. Par après, on remarque que les prix ont commencé à baisser clôturant l'année 1970 à $2.00 US. Cette baisse du prix du V_2O_5 était cependant prévue du fait que les gisements de Highveld Steel & Vanadium Corp. en Afrique du Sud et de l'Union Carbide aux U.S.A. à Wilson Spring ont atteint au cours de 1969-1970 leur potentiel de production se chiffrant respectivement à 23 millions et

10 millions de livres de V_2O_5 par an. De ce fait, Union Carbide était en mesure de satisfaire sa propre demande de V_2O_5 pour la fabrication de ferro-vanadium et Highveld Steel la demande européenne, japonaise et américaine. Cette tendance à la baisse devait encore s'accentuer au cours des premiers six mois de 1971. En effet, si de janvier à mars 1971 le prix resta stable à $2.00 US la livre de V_2O_5, le 1er avril Kerr-McGee baissa le prix de son anhydride vanadique sous forme d'oxyde non fondu à 98%, destiné au marché métallurgique américain, de $0.39 à $1.55 US la livre de V_2O_5. Les détaillants emboîtèrent le pas et baissèrent le prix de l'anhydride vanadique de qualité technique destiné à l'exportation à $1.55. Au début de juillet, Kerr McGee baissa encore de $0.05 et par le fait même, les détaillants cotèrent leur produit à $1.50 US la livre de V_2O_5.

La revue Metals Week du 26 juillet 1971 donnait les prix suivants du vanadium aux Etats-Unis:

Anhydride vanadique: la livre de V_2O_5, (franco mine ou usine)

Oxide noir fondu[2]	$1.50
Séché à l'air[3] (technique)	$2.21
Marchand (principalement exportation)	$1.50

2: anhydride vanadique produit principalement par Kerr McGee et vendu pour le marché métallurgique américain.

3: anhydride vanadique utilisé pour la fabrication de produits chimiques produit principalement par UCC et Foote Mineral Corp.

Ferro-vanadium: la livre de V, emballé, franco lieu d'expédition, frais de transport égaux à ceux du principal producteur le plus proche.

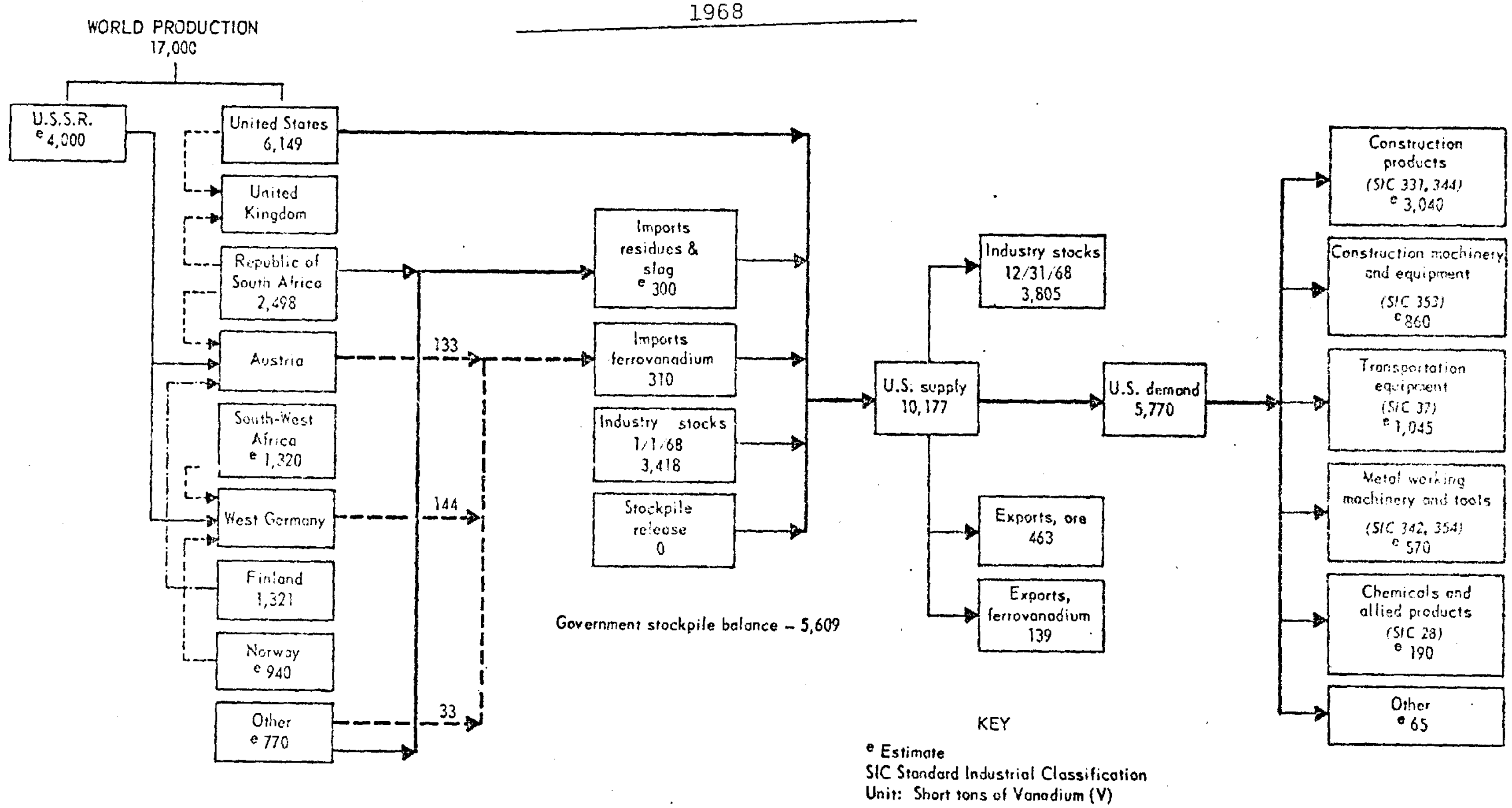
Teneurs courantes	$4.12
Détaillants	$4.25
CARVAN et SOLVAN	$3.48
FEROVAN	$3.68

On remarque donc que depuis juin 1970, une chute marquée du prix du vanadium s'est faite sentir par rapport à la hausse enregistrée entre 1965 et 1970. Comme mentionné précédemment, cette baisse des prix est liée d'une part à l'augmentation de production de Highveld Steel et de l'Union Carbide mais aussi à la baisse (presque 1,000 tonnes courtes) de la consommation américaine enregistrée en 1970 par rapport à 1969. Cependant, en se fiant à diverses revues telles l'American Metal Market, le Metal Bulletin et le Mining Journal, une période de stabilité des prix est attendue au cours des prochaines années avec des prix oscillant entre $1.50 et $2.00 US la livre de V_2O_5. En effet, même si par rapport à 1970, il y avait une reprise importante de la consommation domestique de vanadium, les stocks industriels (juin 1970: 1,400 tonnes courtes de vanadium)[4] et du "General Services Administration" (juin 1970: 2,790 et 1,200 tonnes courtes de vanadium sous forme de pentoxyde de vanadium et de ferro-vanadium respectivement)[5] agiraient comme tampon contre une augmentation importante des prix.

4: Commodity Data Summaries - Janvier 1971
5: Commodity Data Summaries - Janvier 1971

Diagramme 1

OFFRE ET DEMANDE DE VANADIUM
AUX ETATS-UNIS
1968



VII LES PERSPECTIVES D'AVENIR

On a constaté dans les chapitres précédents les faits suivants concernant le marché mondial du vanadium:

1. Que les Etats-Unis dominent une large part de ce marché. En 1968, sur une offre mondiale équivalente à 17,000 t.c. de vanadium, les Etats-Unis en obtenaient 10,177. (Voir diagramme 1) Rapport U.S. entre l'offre et la demande du vanadium en 1968).

2. Que ce marché comprend deux grands agents: les producteurs de vanadium et les consommateurs qui sont les producteurs de ferro-alliages. On constate cependant que dans la majorité des cas les producteurs sont aussi consommateurs. (Exemple: Union Carbide Corp., Susquehanna Western, Highveld Steel & Vanadium Corp., Christiana Spigerwerk).

3. Qu'il est dominé par des entreprises multinationales, verticalement et horizontalement intégrées (exemple: Union Carbide, Anglo-American Corp., Christiana Spigerwek, Rautarrukki Co.).

4. Que le vanadium est récupéré en général comme sous-produit ou co-produit du traitement d'un concentré soit de minerai d'uranium ou de magnetite titanifère. On note cependant que

l'Union Carbide Corp., fait exception à la règle en exploitant en Afrique du Sud et aux Etats-Unis des gisements, où le vanadium est récupéré comme produit primaire.

5. Que le détaillant ne contôle qu'une faible part de ce marché puisqu'en général, le producteur de vanadium vend lui-même ses produits aux consommateurs. (On estime à 5% la part du marché, contrôlé par le détaillant).

6. Qu'aux Etats-Unis, le General Services Administration est potentiellement un important fournisseur de vanadium depuis l'abaissement en mars 1970 des stocks de guerre conventionnels du vanadium. Ce surplus vendable s'évalue actuellement à 3,450 tonnes courtes de vanadium.

De plus, on constate que, depuis les vingt dernières années, les sources d'approvisionnement de vanadium ont changé. En effet, la récupération du vanadium des gisements de magnétite-Ti-V a augmenté le potentiel de production mondiale. Ainsi, depuis les dix dernières années, ce potentiel de production a stimulé la recherche et incité les firmes de ferro-alliages à découvrir de nouvelles applications de produits du vanadium, la mise en marché de ferro-vanadium tel le CARVAN, le SOLVAN et le FEROVAN est en somme l'aboutissement de ces recherches qui offrent à l'industrie sidérurgique des prodruits compétitits.

Les perspectives du marché du vanadium sont liées d'une part à la croissance de la production de l'acier et d'autre part, aux potentiels du développement de ce marché à l'intérieur des économies concernées. Il est évident, par exemple, que l'économie américaine, du fait de sa maturité, possède un potentiel de croissance du marché du vanadium moins élevé que le Japon ou l'Europe. Les perspectives de ces marchés sont observés ci-dessous (voir tableau 16 "Dépôts potentiels de vanadium dans le monde présentement à l'étude").

(i) Etats-Unis

Il existe plusieurs estimations de la demande future de vanadium aux Etats-Unis. Ces estimations évaluent le taux de croissance annuel de cette demande entre 5 et 7 pour cent. Cependant, nous retenons le taux annuel de 5% avancé par les Etats-Unis Bureau of Mines. A ce taux, on estime qu'en

1985, la consommation américaine aura plus que doublé par rapport à celle de 1970. En 1970, la consommation était de 6,300 tonnes de vanadium par an. Pour 1985, on prévoit une fourchette de la consommation en vanadium entre 10,500 et 16,000 tonnes.

Pour satisfaire cette future demande interne, les Etats-Unis devront être tributaires de l'étranger plus que dans le passé. En effet, les grandes sources d'approvisionnement de scories de vanadium de la République de l'Afrique du Sud et très probablement de l'Union Soviétique ont tendance à freiner les investissements nécessaires à la mise en exploitation de gisements américains.

Cependant, le fait que les Etats-unis aient une économie relativement bien développée et qu'ils ne soient responsables que d'un tiers de la consommation mondiale nous permet d'entrevoir dans les autres pays un potentiel de croissance plus élevé aux Etats-Unis.

(ii) Japon

L'absence de statistiques sur la consommation du vanadium concernant le Japon et l'Europe rend difficile l'élaboration de prévisions.

Néanmoins, certaines tendances peuvent être dégagées. Ainsi, le "Metal Bulletin" du 6 juin 1969 note que les Japonais attendent une forte augmentation de la consommation de vanadium suite à certains facteurs qui favorisaient le vanadium plutôt que le colombium comme élément d'alliage dans les aciers de construction à faible alliage et de haute tension. Cette croissance semble être en effet en voie de réalisation puisque récemment le "Engeneering and Mining Journal" de mars 1971 signale le démarrage d'un producteur d'anhydride vanadique à partir de scories de Highveld Steel & Vanadium Corp. de l'Afrique du Sud. L'anhydride vanadique sera subséquemment utilisé pour fabriquer du ferro-vanadium.

En résumé, même si actuellement le Japon semble avoir un marché saturé, ce dernier est promu à une croissance importante d'ici 1980. En effet, le taux de croissance annuel prévu (9.1%) d'ici 1980 pour la production d'acier est un indice clef de la croissance de la consommation de vanadium. Ainsi, on estime que d'ici 1980, le Japon consommera, en vanadium, l'équivalent des Etats-Unis en 1970, soit approximativement 6,000 tonnes.

(iii) L'Europe

Le marché européen semble, d'ici 1985, être destiné à une croissance égale, sinon plus importante que celle envisagée aux Etats-Unis. En effet, même si l'estimation du taux de croissance annuel de l'acier est d'environ 5% (taux supérieur aux Etats-Unis), le marché européen du vanadium reste sujet à un taux de croissance plus élevé, puisqu'il n'a pas encore atteint la maturité de son développement.

VIII CONCLUSION

L'exploitation d'un gisement de magnétite titanifère et vanadifère semble difficilement envisageable sans récupération de co-produits ou sous-produits. En effet, tel que le mentionne le U.S. Bureau of Mines, les procédés de traitement de ces minerais (grillage au sel et lixiviation), afin de récupérer le vanadium, sont encore relativement inefficaces et coûteux.

Par ailleurs, l'écoulement du vanadium se fait dans un marché captif. En effet, les producteurs de vanadium consomment leur propre production ou s'assurent des débouchés pour leur produit bien avant la mise en production du gisement.

Dans le contexte, l'exploitation du gisement du canton de Rinfret soulève plusieurs problèmes, à savoir:

1. les débouchés de produits: le ministère ou tout autre exploitant devra, au préalable, être assuré d'un débouché pour ce type de concentré. L'acquéreur du concentré, par la nature de celui-ci (62.68% Fe, 1.14% V_2O_5 et 8.81% TiO_2), devra récupérer le fer, la titane et le vanadium, s'il désire être rentable.

2. la pauvreté du gisement: le gisement comme tel (teneurs: 31% Fe et 0.5% V_2O_5) paraît pauvre comparé aux autres gisements de même nature, présentement en exploitation dans le monde.

3. les prix et le marché du vanadium: le prix de l'anhydride vanadique (V_2O_5) de qualité technique[1] a baissé plusieurs fois depuis juin 1970, le marché étant très peu actif. Ainsi, à court terme, tous nouveaux producteurs devront créer leur propre marché.

4. des autres concurrents: la récupération du vanadium comme sous-produits du pétrole, de sables bitumineux ou de déchets industriels (exemple: Pétrofina Canada Ltd., Masterloy Products Ltd.) mettra sur le marché , au cours des prochaines années, des quantités importantes d'anhydride vanadique à des coûts de production (30¢ la livre de V_2O_5), relativement moins élevés

Ainsi, l'exploitation de gisements de magnétite titanifère et vanadifère sera, à l'avenir, tout comme elle l'est présentement à quelques exceptions près, envisageable seulement en fonction de la rentabilité de tous les produits du gisement, comme le fer, le titane et le vanadium.

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1. Destiné aux producteurs de ferro-vanadium

REFERENCES

- U.S. Bureau of Mines, Commodity Data Summaries, Publications de janvier 1969, 1970, 1971

- U.S. Bureau of Mines, Minerals Facts & Problems, Edition de 1965 et Edition de 1970

- U.S. Bureau of Mines, Mineral Industry Surveys, Vanadium en 1969 et 1970

- American Metal Market, International Vanadium Section, 13 janvier 1970 et 6 janvier 1971

- Mining Journal, 12 mars 1971, A Look at Vanadium

- L. Kish, The Vanadium-bearing Titaniferous Magnetite Deposit, in Rinfret and Lemoine Township, East of Chibougamau, Québec. Mars 1971

- Metal Bulletin, Vanadium: production and usage. Vendredi, le 23 mai 1969

- Mining Annual Review. Juin 1970 et 1971. Section sur le vanadium par A.G. Thomson

- Annuaire des Minéraux du Canada, Mineral Ressources Branch, Ottawa, Edition de 1965, 1966, 1967, 1968, 1969, 1970. Section sur le vanadium

- Metal Bulletin Special Issue; Ferro-Alloys. Juillet 1966

- Engineering & Mining Journal, mars 1970 et 1971. Vanadium par B.A. Rausch

- U.S. Bureau of Mines, Minerals Yearbook Preprint 1970. Section sur le vanadium

- U.S. Bureau of Mines, Vol. IV. International 1968-1969-1970

- Metals Week, The Ferro-alloy Metals, Vanadium.

  page 16, 29 mars 1971
  page 45, 30 mars 1970
  page 39, 17 mars 1969
  page 34, 13 février 1967

- Bush, Philipp M., Vanadium, A Material Survey. U.S. BuMines, Inf. Circ. 8060, 1961

ANNEXE I

Le tableau ci-dessous illustre l'importance de l'industrie des ferro-alliages aux Etats-Unis ainsi que sa dépendance vis-à-vis l'industrie sidérurgique américaine.

CONSOMMATION DES FERRO-ALLIAGES AUX ETATS-UNIS

- 1969 -

Produits	Tonnage (milliers de tonnes courtes)	Valeur (millions de $)	% utilisé dan le fer et acier
Alliages de manganèse	1,400	220	95
Alliages de silicium	800	200	85
Alliages de chrome	400	150	95
Nickel - scories toutes ses formes	170	420	40
Molybdène comme oxyde	30	110	75
Tungstène comme métal	7	45	20
Vanadium comme Fe-V	6	35	75
Autres alliages	12	20	90
TOTAL	2,285	1,200	

Source: Mining Congress Journal, février 1971.

ANNEXE IA

On constate qu'aux Etats-Unis 88% du tonnage et 69% de la valeur de l'ensemble des ferro-alliages est consommé par l'industrie sidérurgique. Pour sa part, le vanadium, sous-forme de ferro-vanadium est le moins important tandis que les alliages de manganèse sont les plus importants en tonnage et le nickel en terme de valeur. Néanmoins, le "Mineral Facts and Problems" du U.S. Bureau of Mines note que depuis 1960 le taux de les principaux ferro-alliages et il le demeurera jusqu'à la fin du siècle.

Background to the Highveld Project

By IAN F CAIRNS

THE HIGHVELD STEEL & VANADIUM CORPORATION is an integrated iron, steel, and vanadium works, designed and built on a "greenfields" site between 1965 and 1968. The plant is located some 80 miles east of Johannesburg near Clewer, seven miles west of Witbank.

Design started in January 1965 and the first pig-iron was tapped in February 1968. The plant was officially opened on April 18 1969. At rated capacity Highveld will produce annually some 300,000tons of rolled profiles in the range of rails, universal beams and columns, channels, angles and flats, about 120,000tons of rolled or continuously cast blooms, and 23million pounds of V_2O_5 in the form of a 25% V_2O_5 slag. In addition its Vantra division produces some 7million pounds of high purity V_2O_5 in the form of flakes. Highveld is therefore by far the largest producer of vanadium in the world.

The Highveld concept was first conceived in late 1959, at which time Anglo American Corporation of South Africa was investigating—with a view to exercising its option to take over control—the Minerals Engineering Company of SA, operated by American interests. This latter company was endeavouring to exploit the vanadium resources of the vanadium bearing titaniferous magnetites of the Bushveld Igneous Complex by the well-known process of salt roasting and leaching of the finely ground ore. This option was exercised by AAC in 1960 and the company was renamed the Transvaal Vanadium Company. In August 1966 Highveld acquired from the Transvaal Vanadium Company the plant and machinery at its works at Witbank and this works now operates as the Vantra division of Highveld.

The possibility of the co-production of steel and vanadium from the Bushveld magnetites had been highlighted by Dr Wm Bleloch in a paper on "The Electric Smelting of Iron Ores" presented to the Chemical Metallurgical and Min Soc of SA in March 1949.

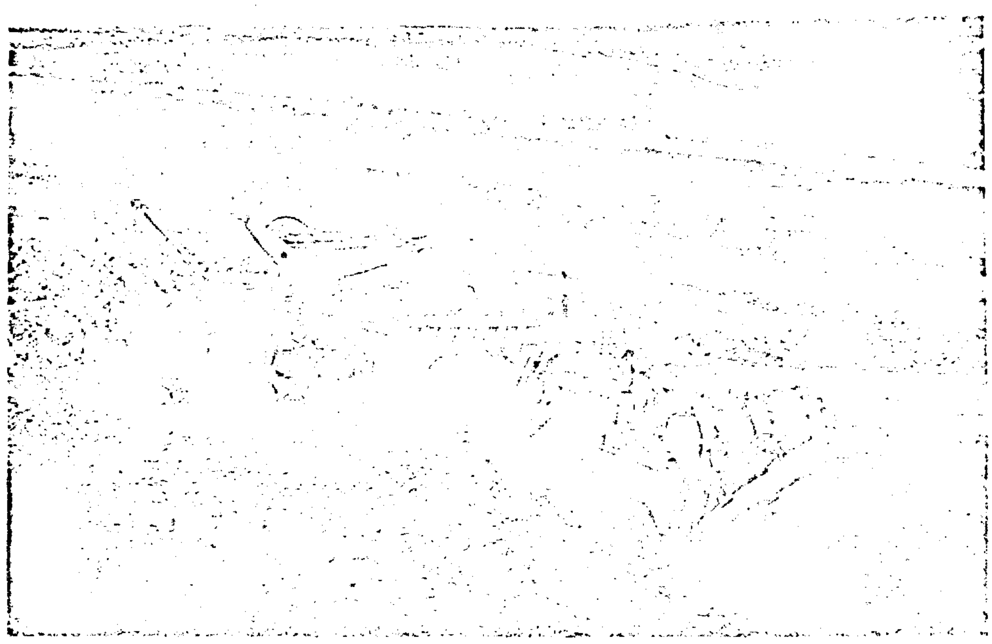
In May 1960 the Highveld Development Company was formed with the following objectives:—

(i) to undertake a major geological exploration to determine the extent of available ore reserves and to acquire the mineral rights;

(ii) to undertake a metallurgical investigation into the economics of steel and vanadium recovery from the ore by means of a large-scale pilot plant based on electric smelting. The high titania content of the ore ruled out the possibility of conventional blast-furnace smelting;

(iii) to carry out a worldwide study of existing vanadium ore reserves and operations, including costs of existing production, and to attempt to assess the world supply and demand in 1966.

Anglo American Corporation allocated an initial R1 million for the capital cost and operation of the pilot plant for one year and the investigation was placed under control of its metallurgical development department. A preliminary assessment of the economics of the project 10 months after the start-up of the pilot plant was promised. Over the



Earthmoving machine removing ore for the Highveld Works.

whole period of this investigation some R3·4million was eventually spent.

The geological exploration lasted three years and proved up 200million tons of ore to open-cast limits with very consistent values averaging 56% iron, 13% titanium dioxide, and vanadium pentoxide varying between 1·5 to 1·9%.

While the metallurgical pilot plant was under construction, prereduction and electric smelting tests were carried out by Anglo American engineers in co-operation with Elektrokemisk, Norway, and these tests established that the high cost of electric power for smelting could be reduced by some 50% by prereducing the ore in a rotary kiln prior to smelting.

The pilot plant was put into operation in April 1961.

Plant equipment installed was as follows:—

1 One 3ft 6in × 50ft (1·1m × 15m) pulverised coal, counter-current-fired kiln, well instrumented.

2 One 1500kVA submerged arc smelting furnace.

3 One 1500kVA open arc in-line smelting furnace.

4 One pig-casting bay.

5 Two 1750kVA electric arc melting furnaces.

6 Two 3ton side-blown converters converted to BOF vessels.

7 One 5ton Storakopperbergs shaking ladle.

8 One 5ton Resonator (steelmaking vessel).

9 Liquid oxygen vaporization plant.

All auxiliary equipment including overhead cranes, ladles, ladle-drying equipment, kiln feed blending, etc.

The plant operated until May 1963, during which time some 5000tons of vanadium bearing pig-iron was produced of which some 1500tons were blown to steel. The various grades of ingot steel were rolled and evaluated at the works of Scaw Metals.

Ultimate process selection was as follows:—

1 Prereduction of the ore to 45% reduction. Further reduction gives still lower power consumption but higher vanadium values in the smelter slag and low-carbon hot metal.

2 Smelting in submerged arc smelting furnaces.

3 Removal of vanadium from the hot metal by oxygen blowing in a shaking ladle, to produce a solid 25% V_2O_5 slag and "blown metal".

4 Conversion of "blown metal" to steel in BOF vessel.

In March 1962 the "Preliminary Report and Assessment of the Highveld Project" was produced. This covered estimated capital and operating costs for a 600,000tons/year plant and showed that a successful metallurgical process had been developed which was economically viable. From preliminary market surveys up to that time the report anticipated that by 1966 South Africa would be able to sell on world markets some 16 to 20million pounds of vanadium pentoxide. The report recommended that an integrated iron, steel, and vanadium plant be established.

The potential of the scheme evident from the report inspired further interest. Geological exploration and acquisition of mineral rights continued and the pilot plant operations were extended for another year. Several hundreds of tons of Highveld vanadium pig-iron were shipped to Sweden, Germany, and Austria where confirmatory tests on steelmaking were carried out. In one series of tests in Austria a series of vanadium bearing steels was produced which when rolled to plate showed excellent high-yield properties. In Germany deep-drawing sheets of top quality were produced.

The preliminary report of March 1962 was produced after only 10 months of pilot plant operation and capital cost estimates were done without any detailed engineering drawings. It was therefore decided to sponsor an independent engineering study and Davy and United Engineering Company, of Sheffield, was selected for this purpose. A Davy and United team of engineers came to South Africa early in 1963 and, working in close association with the Highveld team, carried out a detailed engineering study.

The Davy and United report was presented in September 1963. It covered all aspects of plant design, capital cost, and operating costs and, in general, confirmed the estimates of the Highveld March 1962 report.

The vanadium market study on a world basis continued through 1962 and 1963 and despite the very poor market for vanadium in 1963, a major change in the supply and demand position evidenced itself in 1964, when it appeared that for the first time world consumption of vanadium looked as though it would exceed production. In April 1964 the Vanadium Corporation of America indicated its willingness to enter into a long-term commitment for the supply of vanadium slag.

With the establishment of adequate ore reserves, the successful development of a metallurgical process to produce steel and vanadium from the Bushveld magnetites, the confirmation of the 1962 report capital estimates, by Davy and United, and the growing demand for vanadium which established that firm contracts could be made for the sale of Highveld slag, a decision was taken in November 1964 to proceed with the project and install an integrated iron, steel, and vanadium plant.

Davy and United was commissioned to design the plant in January 1965 and was appointed engineer, agent, and supervisor on site in September 1965.

The original decision in November 1964 was to install a three-unit smelter plant, but in June 1965 it was decided to install a four-unit smelter with a vanadium hot metal capacity of 480,000tons/year. This decision was taken when it became evident by June 1965 that a three-unit smelter would not meet anticipated vanadium demand for slag from American and European ferro-vanadium producers.

The site chosen for the steelworks seven miles west of Witbank has many advantages.

1 It is located on the main railway line from Pretoria to Lourenço Marques, the port through which slag and steel products are exported. There are rail connections to the Johannesburg area and South African ports.

2 No5 seam Witbank coal, the only South African coal ideally suited to the smelting process used at Highveld, is obtained from the Apex Mine of the Greenside Colliery only seven miles (11km) distant.
No2 seam coal used for firing the kilns is abundant in the Witbank area.

3 By extending the existing Witbank—Middleburg—Stoffberg railway line some 22 miles to Roossenekal, the site of the Mapoch's Mine, ore could be railed directly to the steelworks.

4 Cheap power is available from the Eastern Transvaal system of the Electricity Supply Commission.

5 A reliable water supply based on water from the Witbank Municipality dam is readily available.

6 Witbank is a developing industrial town and housing sites were available where the total work force could be accommodated.

How the Project was Organised

By IAN F CAIRNS

THE DECISION TO PROCEED with the Highveld project was made by the Anglo American Corporation of South Africa towards the end of November 1964. In January 1965 Davy and United was commissioned to design the plant and in September 1965 was appointed engineer, agent, and supervisor on site.

The possible use of steelworks consultants on the Highveld project had been considered in 1963, but this was rejected on the grounds that the Highveld plant up to and including steelmaking was the first of its kind in the world, and as its design had to be based on the pilot plant experience, the Highveld team had to take overall process responsibility for the equipment installed. The Highveld team felt that it could discharge these responsibilities most effectively working directly with an iron and steel works engineering company, rather than more remotely through consultants.

The appointment of Davy and United as engineer for the project caused initial alarm among the many potential equipment suppliers around the world, who felt that they could be placed at a disadvantage in quoting for plant and equipment to our engineer whose associated companies in the Davy-Ashmore group might also be quoting on the same job. Some suppliers also felt that the presentation of detailed tenders and drawings for adjudication by a potential competitor was outside all normal engineering etiquette. These misgivings were understandable, but had to be overcome to enable Highveld to purchase the best possible equipment at the most advantageous prices around the world.

Over the period 1960 to 1964 the Highveld team had had close contact with many of these approved equipment suppliers, and was indebted to them for help in preparing early estimates and for the part many of them played in supplying data and drawings for the 1963 Davy report. These personal associations helped allay some of the doubts, and, of course, with 1965 to 1966 being very much a buyers' market, this fact no doubt had its influence. But further steps were taken to ensure fair and equitable treatment to all tenderers. Two forms of "invitation to tender" documents were drawn up. Where no Davy-Ashmore group company was asked to tender on any particular section of the plant, tenderers were requested to send their tenders complete with technical specifications and quotations direct to our engineer with separate copies to Highveld management. The Davy and United team evaluated and assessed these and presented their recommendations to Highveld management which at all times made the final award. Where a Davy-Ashmore group company was tendering, all tenderers were requested to send to our engineer their full technical specifications with copies to Highveld. Quotations, however, were sent only to Highveld. In this manner equipment suppliers were assured of fair and impartial consideration of their tenders.

This system worked well and the award of contracts to the value of R13million to Davy-Ashmore group companies out of a total hardware bill of some R80million is a tribute to the integrity and impartiality of the Davy and United Witbank team in its recommendations. Comparative bids were called for all sections of the plant with the exception of the electric smelting furnaces, which were awarded to Elektrokemisk, of Norway, in acknowledgment of its very great interest and assistance during the pilot plant operations.

For its work as engineer, agent, and site supervisor, Davy and United was paid a predetermined fixed fee in monthly instalments over the life of the contract.

HIGHVELD MANAGEMENT AND ITS RELATIONSHIP WITH THE DAVY-UNITED WITBANK TEAM

From its inception the Highveld project had been operated under the technical direction of the Anglo American Corporation's metallurgical development department, and in August 1965 the senior members of that department were appointed as general manager, assistant general manager, engineering manager, and administrative manager of Highveld.

This team was charged with the overall technical and financial liaison with Davy and United and was responsible to the Highveld board through the Highveld executive committee. This committee, under the chairmanship of the Highveld deputy chairman, was composed of the managing director, two executive directors, and a manager of Anglo American Corporation, and the four senior members of Highveld management. The composition of the Highveld team and that of the executive committee remained virtually unchanged from the decision to proceed with the project until after the plant had been commissioned. Divisional managers and engineers were engaged, so that in most cases they could take part in the detailed planning and adjudication of tenders for their own sections of the plant.

While the Davy team was in South Africa there was daily contact with the Highveld technical team. When the major Davy effort was in the United Kingdom, Highveld maintained a permanent senior technical representative in their office. For most of this period also the Highveld engineering manager, assisted as required by divisional managers and engineers, was either resident in or on a regular visiting basis to Sheffield.

The executive committee held bi-weekly meetings to discuss progress and financial reports.

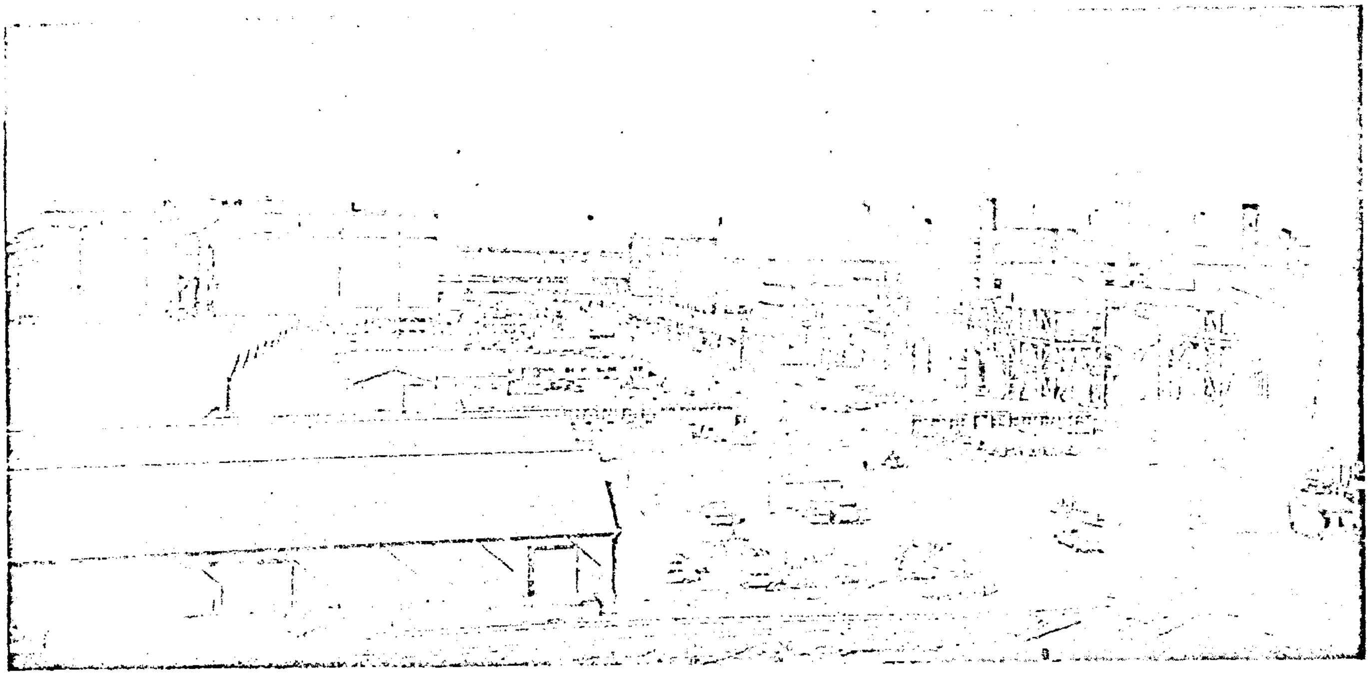
No major contracts were placed until ratified by this committee and no over-expenditure against budget was allowed without executive approval. Where urgent approvals were required, ad hoc meetings of the executive were convened.

The Davy team submitted a detailed monthly report covering orders placed, status of manufacture based on expediters reports, a full report on construction and expenditure to date compared to budget provisions and showing the foreign currencies involved.

Meetings were held quarterly between the Davy team and Davy-United senior management and the Highveld executive. At these meetings, generally held in Johannesburg and later in Witbank, progress was reviewed and policy decisions made where these were necessary to maintain job momentum. The disposition of the various elements of the Davy team was reviewed at these meetings and amended as dictated by changing circumstance.

Negotiation with Government and municipal departments for the supply of power, water, railway extensions, etc, were initiated by the Highveld team. All job accounting was done by Davy and United and payment was made direct by Highveld to contractors.

No housing was available for the construction crews and



General view of the plant: the rotary kilns and electric smelting furnaces are on the right.

Davy engineers in the Witbank area. To this end Highveld put forward its employee housing programme and all contractors labour and engineers were housed in company houses or flats. African labour was accommodated in a central temporary camp adjacent to the plant site.

BASE OF OPERATION AND ORGANISATION OF THE DAVY WITBANK TEAM

The Davy-United involvement in the Highveld project was divided into three separate phases, namely:—

1 The pre-contract period from January 1965 to October 1965, when the contract planning team was located in Johannesburg.

2 The period from November 1965 when the Davy Witbank contract team was set up in Sheffield and operated from that base until the phasing out period from late 1966 to September 1967.

3 The final period, starting late in 1966, when the transfer started of key divisional co-ordinating engineers to Witbank where they helped co-ordinate the activities of contractors, engineers and inspectors for the plant division they had designed.

The project manager took up residence in South Africa in March 1967, and the final move of engineering staff to Witbank was completed around September 1967.

The contract planning team established itself in the Johannesburg office of Davy-Ashmore (SA) early in January 1965. Most of the engineers concerned had been members of the team which carried out the feasibility study during 1963.

The team's terms of reference were the following:—

1 To prepare a plant design based on a three-unit smelter plant with a capacity of 360,000tons of hot metal/year. Design had to allow for later extension to provide a six-unit smelter. In June 1965 it was decided to install initially a four-unit smelter plant with a rated capacity of 480,000tons/year.

2 To prepare technical and metallurgical definitions of plant equipment and issue preliminary enquiry specifications.

3 To examine tenders received and in collaboration with Highveld determine preferred suppliers and contractors for the major process plant and buildings.

4 To prepare a budget estimate of the cost of the steelworks project broken down in detail for each division of the plant.

5 To prepare a preliminary start-up and commissioning programme for the whole steelworks.

It had originally been intended that Highveld would await the budget estimate before making a final decision to go ahead with the project, but in effect the site levelling contract was awarded in June 1965.

The Davy design team during this period was in daily contact with Highveld. While the plant called for in 1965 was radically different in end product and capacity from that on which the 1963 feasibility study was based, the mass of data produced in 1963 was of inestimable help in speeding the programme. Added to this, most of the engineers concerned had been on the feasibility study and knew Johannesburg and quickly settled into the routine.

There was a very satisfactory response when enquiry documents were issued and many teams of engineers visited Johannesburg from overseas for on-the-spot discussion with Davy and Highveld. By the time the design team left Johannesburg in October 1965 letters of intent had been given for much of the equipment and the work was sufficiently advanced so that it was possible to award the balance of the major civil and mechanical contracts between November 1965 and February 1966.

The contract appointing Davy and United as engineer, agent, and supervisor on site was signed in September 1965, and the Davy Witbank team was formed and started operation in Sheffield. The decision to make Sheffield the base of operation for the work of the detailed co-ordination design phase was largely dictated by the fact that much of the plant was of British and European design and it was felt that liaison with equipment suppliers would be easier from Sheffield.

The design team returned to the UK with its families in October 1965 and was incorporated into the Davy Witbank team which started operation on November 1 1965. At this time the leader of the design team joined the staff of Highveld as steelplant manager. He returned to Sheffield where he was the Highveld team representative for the next two years in the Witbank team office.

Fig1 shows the chart of management of the Davy Witbank contract team which was made up of the original design team and other specialist engineers and staff drawn from Davy group companies. The Witbank contract team functioned virtually as a separate company with its own office, telephone exchange, telex, print room, letterheads, etc. At any time, however, it could call on specialist help from other Davy-Ashmore group companies. To augment its mechanical and electrical services team Davy utilised some staff of McLellan & Partners located at West Byfleet, near London. At all times the managing director of Davy and United was in direct contact with the Witbank contract project manager.

As will be seen from the chart of management, the project manager headed a team with three clear-cut functions, of procurement, engineering, and construction. Each of these divisions was headed by a manager who was responsible for the operation of his division regardless of the location of his staff. The manager of procurement, for instance, spent most of his time in Johannesburg, but he had staff operating in Sheffield, London, Johannesburg, and Witbank.

While many orders for main sections of the plant had already been placed before the Davy contract team was formed in Sheffield, there were still a great many more for ancillary equipment to be placed including most of the mechanical and electrical services division, mill electrics, etc. As earlier, the same procedure system was adopted.

After technical and metallurgical definitions for each plant item and process parameters had been defined and agreed with Highveld, this was passed to the divisional co-ordinating engineer, who developed the definition into an engineering enquiry which was passed to the procurement section. Based on the network planning charts, tender closing dates, times for design and supply were assessed and the engineering purchase specification and related programming data were passed to the purchasing engineer, who added the routine standard enquiry documentation and issued the final call for tender. The standard enquiry documents set out instructions to tenderers, engineering instructions and definition of technical data to be supplied, shipping, packing, and marking instructions, contract conditions, engineering standards, cost codes, price variation formulae, etc.

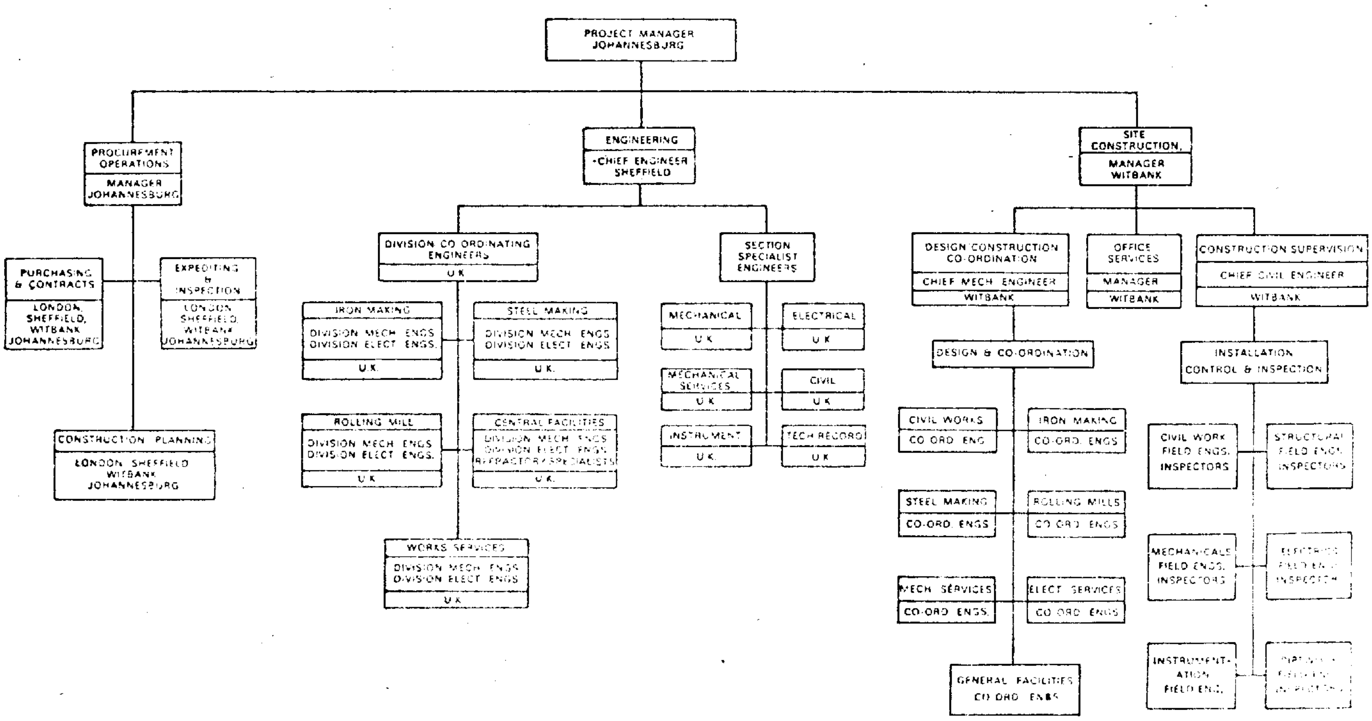
During the tendering period and very often after orders were placed and detailed design was in progress, many meetings were held to amplify tender specifications or make design adjustments. All changes to original tender requirements were carefully minuted and referred for ratification to Highveld. The final purchase inquiry authority which was the basis of authority to place any contract or order showed the budget cost, the prices quoted by each competing tenderer and the recommended tenderer. These PIAs had to be countersigned by the general manager and engineering manager of Highveld before any order could be placed. Any later variation in the accepted price due to improvement in design or rearrangement to allow inter-face compatability of one supplier's equipment with another, had to be the subject of a PIA modification drawn up by the co-ordination engineer. Any such variations were included in the Davy monthly report.

The checking of designs from a very large number of suppliers in the fields of civil, mechanical, structural, and instrumentation services and to ensure that these, when assembled together would make a workable whole, was a formidable task.

To this end all general arrangements were checked and approved before detailed design was completed and conversely detail design was checked to see that it lay within the general arrangement parameters.

As in all such projects, finalisation of civil foundation drawings proved the most troublesome, due to the fact that civil design must await detailed mechanical and electrical and services design, but the starting point on site must always be civil foundations. Some 750 civil drawings from suppliers were checked, modified, and reduced to 300 foundation general arrangement drawings which were

1 *Chart of the management structure of the Witbank team.*



forwarded to the civil engineering contractor for final civil design and detailing. Inevitably with so many suppliers, some at a later stage found they had to make last-minute alterations to accommodate electrical and mechanical services.

For electrical and mechanical services such as various grades of water, gas, oxygen, etc, the detailed requirements of each plant division had to be assessed from suppliers and these had to be co-ordinated to give a logical flowsheet for overall plant installation.

Over 50,000 drawings were reviewed to ensure that they met tender specifications, clearances, and compatability with other equipment and the team prepared some 4000 drawings.

The structural design of buildings and foundations was carried out by South African contractors and all drawings and calculations were checked by the Witbank team.

All electrical systems, water sewage and gas systems were designed by the Witbank team.

It was appreciated early on, that the chart of accounts developed by the design team in South Africa was inadequate. A cost coding system was developed which not only catered for capital expenditure, but could be used for ultimate production and maintenance cost control. This system consisted of symbols and numbers which identified the eight divisions of the integrated works, sub divisions, and plant items. The cost code also differentiated between civils, mechanicals, electricals, instrumentation spares, etc, and was tailored to suit computerised systems of accounting, inventory control, etc, to be adopted later at Highveld.

This phase of procurement and co-ordination engineering was largely completed towards the end of 1966, and key members of the engineering and planning team started moving to South Africa. By March 1967 the project manager was resident in South Africa and the Davy team on site took over all contract duties some months later.

The function of programming, purchasing, progressing, expediting, and inspection were all the responsibility of the procurement manager.

Computerised critical path planning was not adopted by the programming and planning section, and a modified type of critical path network plus bar charts was utilised. Programmes were built up from data obtained from hundreds of equipment suppliers covering design, manufacture, delivery, and erection times. Divisional programmes were first built up and correlated into an overall master programme. It is interesting to note that the start-up and commissioning programme produced in January 1965 called for the start-up of No1 electric smelter on April 1 1968, and iron was tapped from this furnace on February 28 1968.

Over the contract period the purchasing section issued over 3000 orders and amendments ranging in value from a few rand to one of R9million and totalling over R80-million. Of this total expenditure within the plant perimeter just over 80% was spent in South Africa, a notable tribute to the engineering potential of that country.

Construction on site was directed by the Davy site manager, who had complete jurisdiction over all contractors and site activities. At the peak period over 4000 men were engaged on site, working for some 67 companies.

The Davy site staff was initially limited to the site manager, a chief mechanical engineer, and chief civil engineer, an office manager, and a few assistants. As site work progressed, however, more of the design engineering staff were transferred from Sheffield to Witbank to co-ordinate the work of the construction contractors and suppliers installation supervisors. At peak when the whole contract was operated from the Witbank site, Davy had a staff of 65 composed of engineers, inspectors, draughtsmen, accountancy, and administrative staff. On completion of construction of an item of plant, Davy engineers inspected it mechanically and electrically. Electrical circuitry was checked without power on, followed by hot testing of drives, etc, under no-load conditions, first individually then interlocked and in sequence. Highveld engineers witnessed these tests and, if satisfactory, issued acceptance certificates with exceptions as noted.

As a section of plant was to be put into commission, a count-down procedure was adopted, and only after its successful conclusion was the process started.

In the early weeks of operation Davy engineers assisted the Highveld engineers and operators, and gave further assistance through lectures to operators and writing "operator instructions".

Throughout the construction period regular site meetings were held with all construction contractors. These were convened under the chairmanship of the site engineer, the project manager, or Highveld management, by agreement between engineer and client and as circumstance demanded. These were lively meetings attended by contractors senior management and site staff, and overall were most productive. During the design and equipment selection phase of the contract, the co-operation of steelworks managements around the world who agreed to, and arranged, visits to their plants by the Davy and Highveld teams, was greatly appreciated and proved invaluable in selection of the best equipment design.

SUPPLY SOURCES

Nearly 300 design and supply companies contributed to the Highveld project and these were scattered through Belgium, France, Norway, Sweden, Germany, Holland, Italy, Japan, South Africa, Switzerland, the United Kingdom, and the United States. Most imports were through Lourenço Marques and no overseas port of shipment was under 7000miles (11,200km) from that port. Some equipment was also imported through Durban, including the finishing mill housings. These were hauled on a 170ton trailer to Witbank, some 500miles (800km) by road.

The great bulk of the 60,000tons of plant and equipment and thousands of tons of refractories from South African sources came from the workshops of the Transvaal, but useful contributions were made by shops in Cape Town, Durban, and East London. The closure of the Suez Canal, the UK dockers' strike of July and August 1967, and a major-scale fire in one of the fast cargo ships from Europe carrying about R½million of equipment for Highveld all raised temporary alarms at critical times. Fortunately, no equipment was lost.

REFLECTIONS ON PROJECT ORGANISATION

Looking back over the planning and construction years, the project was a very successful accomplishment carried out in excellent time. A lot of thought and planning had gone into the project before the November 1964 decision to build the plant.

On the Davy side continuity was maintained in that some of the engineers who took part in the preliminary talks which led to the 1963 feasibility study were on the Highveld site when the plant was commissioned. Again, nearly all of the senior engineers appointed to the Davy Witbank team saw the project through to conclusion. The use of the divisional design engineers to assist later with the co-ordination of site erection was useful both to the engineers concerned and the smooth progress of construction. On the Highveld side the small management team had built and operated the pilot plant and developed the process up to steelmaking. They had lived with the project for five years, were very keen to see it developed, and, accordingly, drew up a very tight schedule for its completion. On the simple basis that there was no one to argue about decisions, these were made quickly and generally got immediate approval of the executive committee.

Again in the middle '60s the creation of a new "greenfields" steelworks was something of a rarity and most equipment suppliers were short of work. Consequently, competition was keen and, with very few exceptions, the performance of successful tenderers in the supply of the necessary design drawings and manufacture was of a high standard and expeditiously carried out.

Because of exchange control in South Africa, it was necessary, in the case of overseas orders, to have as much of the equipment as possible manufactured in South Africa. A target of 50% on equipment value was set and while this was a disappointment to many overseas suppliers with empty shops, they co-operated magnificently. In the event, of the ÷R80million spent within the Highveld perimeter, just over 80% of this value was paid in South African currency. That this was possible in the heavy equipment field is a tribute to the growing stature of South African engineering, but also it was due in some measure to the generosity of some UK and European companies who sent out engineers to South African shops and freely gave advice in specialist techniques that led to economies in cost.

To the many companies around the world which played their part in making a success of the project, Highveld would like to say "Thank you for a job well done".

As the plant moved into production, most participants would agree that the Highveld project was a stimulating experience and an example of what can be achieved by true international co-operation.

Civil Engineering

SITE SURVEY WORK, soils investigation, clearance, and grading of the site and the establishing of construction services were all essential forerunners to starting site civil works. The latter included main site drainage, construction roads, railtrack systems, construction electrical power supplies, housing and feeding facilities for African labour employed by the contractors, perimeter fencing, temporary domestic water supply, site offices for construction staff, preparation of contractors' storage compounds, workshops, etc.

These facilities had to be so designed and located as to avoid prejudicing the ultimate permanent installations and yet be available until the end of the construction period. In addition, systems were set up for the receipt of materials and equipment, for the operation of first aid and security services, and for the control of all the contractors' activities on site by the enforcement of site regulations and safe working conditions.

At the peak, as mentioned elsewhere, construction work demanded 10,000gal/h (45,460 litres/h) of domestic water and 3MVA of power. Three 54in (1380mm) dia mains were installed for surface drainage, but serious troubles were experienced during construction. This was due to the water table, which rose to an unprecedented level because of a season of very heavy rains following several years of drought. Extensive use was made of concrete piling in all areas of the works, but particularly in the rolling mill, and some foundation designs had to be modified to avoid the possibility of floating.

A concrete batching plant was established with a capacity of 750cu yd/day (573cu m/day), but this frequently proved to be a limiting factor in meeting the civil programme. In order to meet the overall construction programme, building column foundations were frequently completed prior to the design of those for mechanical plant so that structural erection could commence early to reduce interference between the civil and building contractors. This involved considerable engineering judgment with regard to founding depths of the columns to permit the later safe construction of plant foundations.

Plant foundations and structures ranged from an excavation of 60ft (18·3m) deep for the mill scale pit to a structure 66ft (20·1m) high for the kiln bunker.

In the ironmaking area 33,400cu yd (25·500cu m) of concrete were used to construct the ironplant foundations and concrete structures. 7100tons of mechanical equipment, 6400tons of structural steel, and 8850hp (6600kW), consisting of 430 drives, are installed, together with the necessary 3½ miles (5·6km) of distribution cabling, 83 miles (135km) of drive cabling, and 19 miles (30·5km) of lighting cables.

The foundations required for the casting machines involved excavating 16,000cu yd (12,200cu m) of earth, and the pouring of some 9650cu yd (7350cu m) of concrete. The component parts of the casting machines have an aggregate weight of just under 5000tons.

For the rolling mill foundations over 100,000cu yd (76,460cu m) of concrete were used for the foundations, and 26,000tons of equipment and structural buildings were erected in the rolling mill area. To supply power for this equipment 2·5million ft (76,200m) of cable were required.

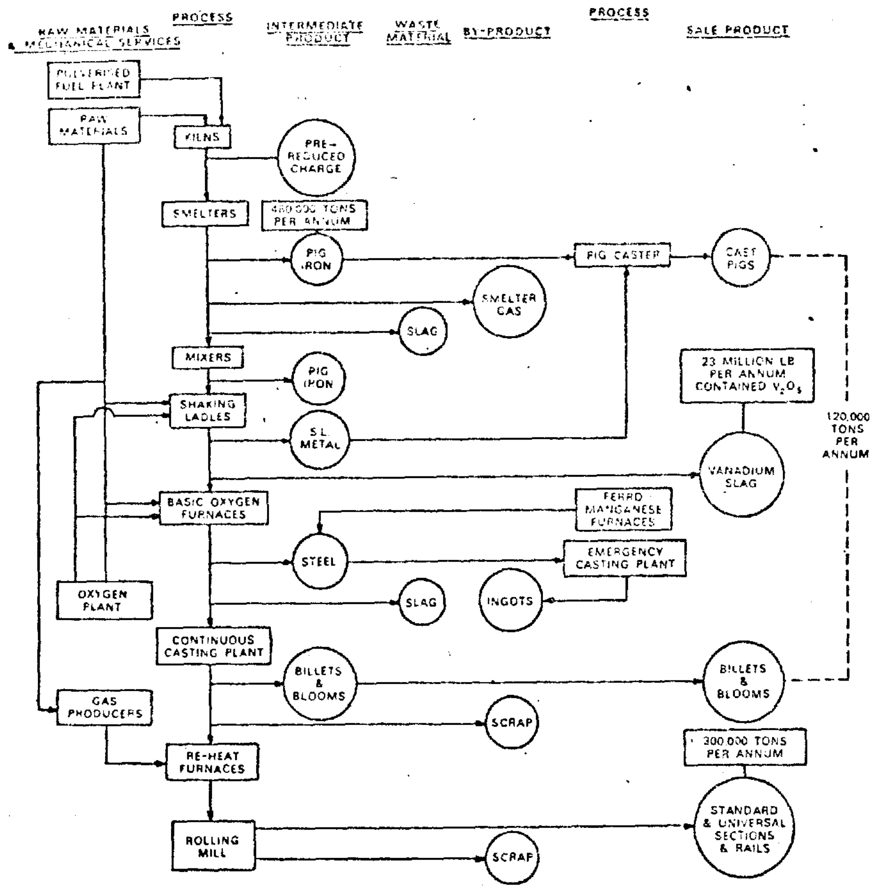
Process Flow and Plant Layout

PROCESS FLOW

Fig2 IS AN OUTLINE OF the process flow of the whole plant from the raw materials to the saleable products, the latter being (1) pig-iron, (2) steel, as blooms, billets, rails, and standard and universal sections, and (3) vanadium containing slag (nominally 25% vanadium pentoxide).

The raw materials, which comprise iron ore, coal, limestone, dolomite, and silica are carefully proportioned and fed at the desired rate into the rotary kiln fired with pulverised fuel. The hot kiln product containing partially pre-reduced iron ore, char, and fluxing materials is charged, via refractory lined storage hoppers, to submerged arc electric smelting furnaces where the iron-ore reduction is completed and liquid pig-iron and slag produced. The slag is tapped into slag pots for disposal and the pig-iron, containing vanadium, is transferred for storage in hot metal mixers.

Weighed quantities of metal are extracted from the mixer by direct pouring into the shaking ladle, held by crane. The shaking ladle is transferred to its emplacement position where coolant in the form of iron ore or scrap is added, the metal is agitated by shaking and oxygen blown onto the metal surface to remove vanadium and other metalloids.



2 *Diagram of process flow at Witbank.*

The shaking ladle is then transferred to the basic oxygen furnace area, the metal poured into the furnace, fluxing materials and scrap added, and the metal refined to steel by blowing with oxygen. The slag containing vanadium pentoxide is removed from the shaking ladle by up-ending in a deslagging area. Alternatively, the pig-iron, or the vanadium-free shaking ladle metal, is transferred to the pig-casting plant for direct casting into pigs.

The steel made in the BOF is tapped into a preheated casting ladle. The ladle is transferred to the continuous casting plant and the steel cast to produce the required ingot sections. Emergency facilities are provided for conventional casting of steel into ingots. The continuously cast ingots are transferred to the walking beam reheat furnaces, from whence they are extracted and passed to the rolling mills for producing billets, rails, standard and universal sections.

INTEGRATED PLANT LAYOUT

The layout of the entire plant is shown in **Fig3**. It was evolved to give the minimum capital and operating cost in the first phase of development, while providing facilities for expansion for later phases. This expansion will be to the westward, on land available for the purpose and adequate for an ultimate developed capacity of 2million tons/annum.

The ironmaking, steelmaking, rolling mill, and central maintenance departments are separately located about the central north-south road. Hot metal transfer from the ironplant to the steelplant is by rail, a distance of 1100yd (1000m), and ingot transfer from the steelplant to the mill is by road, a distance of 100yd (91m).

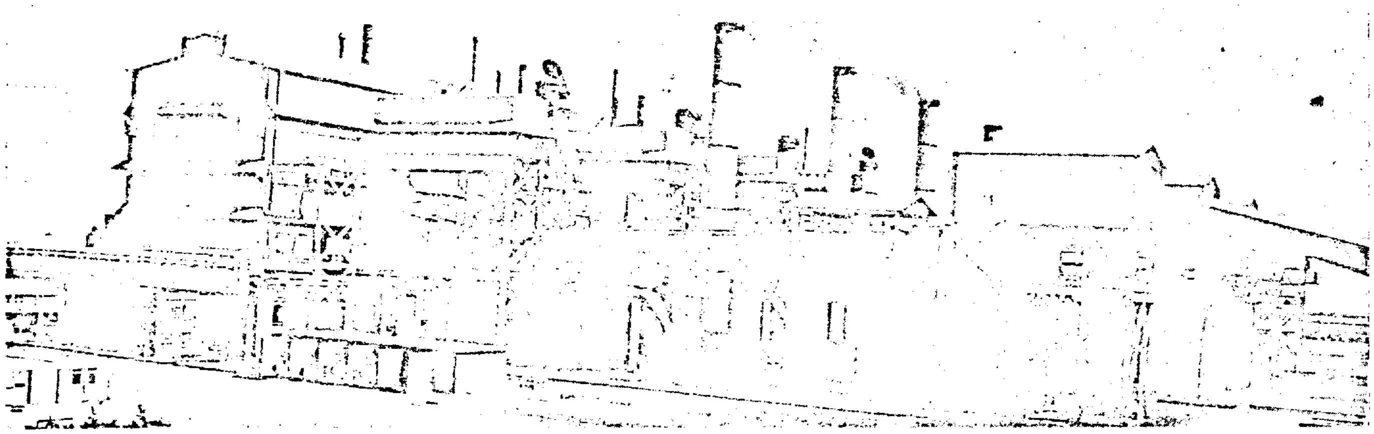
All road transport enters and leaves via the main access gate and weighbridges at the north-east corner of the site. Raw materials which are supplied by rail enter from the north, after which the flow is southward, ending in the mill product leaving from the south east. The vanadium slag leaves the site on the east side. The South African Railways/Highveld exchange sidings, through which all rail traffic must pass, are located off the south-east corner of the site, the distance from there to the ore reception bunker being 2950yd (2700m).

Ironmaking Plant

HIGHVELD'S MAGNETITE ORES contain significant amounts of titanium and vanadium, the composition range being as follows: Fe, 55 to 57%; Ti, 12 to 15%; V_2O_5, 1·4 to 1·9%; Al_2O_3, 2·5 to 3·5%; MgO, 0·4 to 1·0%; SiO_2, 1·0 to 1·8%; S, 0·02 to 0·03%; P, less than 0·05%; CaO, less than 0·01%; Cr_2O_3, 0·15 to 0·3%; Cu, 0·02 to 0·03%; Ni 0·03 to 0·07%. The reduction of such ores in blast furnaces has never proved a practical production process. By electric smelting, however, titanium and vanadium bearing ores can be successfully reduced, as has been done, for example, for many years by the Norwegian company, Christiania Spigerverk A/S, in whose process vanadium is recovered as a valuable by-product.

At Highveld, the "low silicon iron" process has been adopted, whereby most of the vanadium in the ores is conserved in the metal whereas most of the titanium remains in the slag.

The ironmaking plant comprises four production lines fed from a common raw materials stockyard and handling area. Each line includes a prereduction kiln, hot charge handling equipment, and a smelting furnace (**Fig4**).



View of the ironmaking plant.

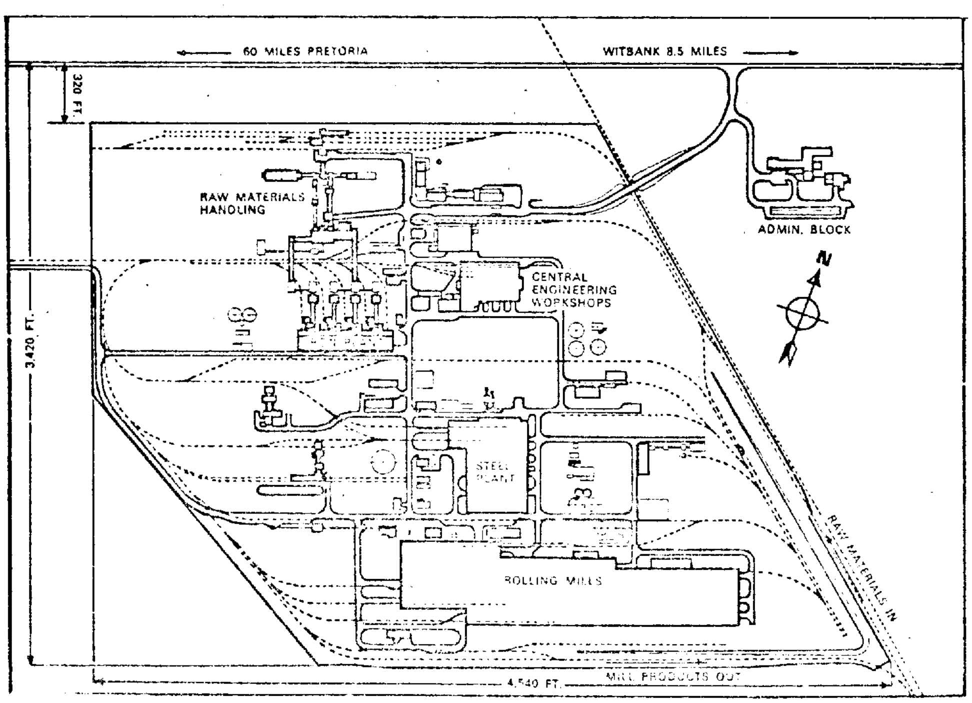
RAW MATERIALS

These materials are iron ore, coal for prereduction, limestone, dolomite, silica, and duff coal, which is required for the production of pulverised fuel (PF) for kiln firing. With the exception of silica, coal, and duff coal, which come by road, these materials are delivered by rail. The iron ore is bottom discharged from the wagons into concrete ground hoppers of 800tons capacity. The ore is reclaimed by plough and transported at 550tons/h on conveyors to the iron-ore stockpile. This is of concrete construction, with 22,000ton capacity hoppers below ground and an "A" frame construction above ground, which supports the feed conveyor and tripper.

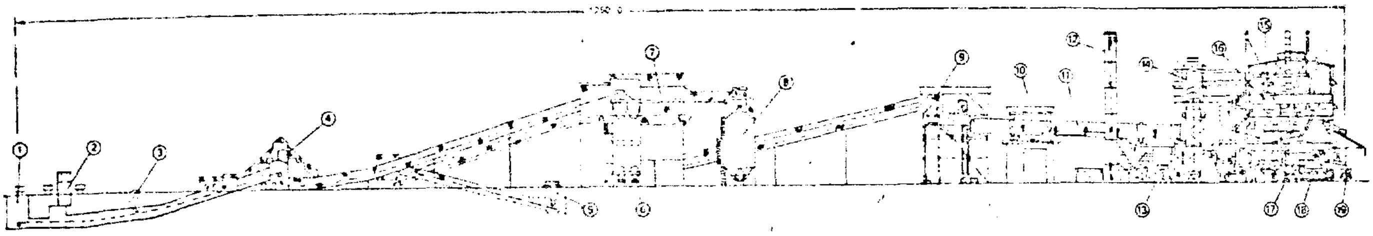
All the other materials, except silica, are discharged into a ground reception hopper by a wagon tippler handling up to 15 wagons/h; the wagons being fed to and from the tippler by an electric shunting mule and weighed automatically before and after tipping. The material from the tippler hopper is reclaimed by vibrating feeders and fed to the relevant storage area by the conveyor route selected from a central console control.

Coal is routed direct to an 8000tons capacity coal stockpile of similar design to the ore stockpile, except that it is sub-divided to permit the emptying of compartments in rotation, thus reducing the possibility of spontaneous combustion.

Dolomite and limestone are taken to the kiln storage bunkers and duff coal to a separate storage bunker which supplies the PF plant. In the event of ore being received in wagons which cannot be bottom discharged, the wagon



3 *Layout of the Witbank plant.*

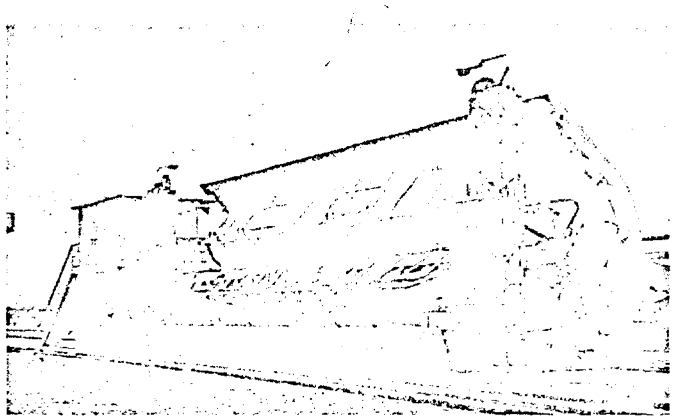


KEY: 1—Ground reception hoppers; 2—wagon tippler; 3—emergency ground hopper; 4—stockpiles; 5—silica hopper; 6—weighfeeders; 7—kiln bunkers; 8—duff coal bunker; 9—pulverised fuel hopper; 10—kiln drive house; 11—pre-reduction kiln; 12—waste gas stack; 13—multiclones; 14—spray tower; 15—hot charge car; 16—hot charge hoppers; 17—electric furnace; 18—slag pot car; 19—Kiling ladle car.

4 *Section through the ironmaking plant.*

tippler is used and the material routed to the ore stockpile. In addition an emergency ground hopper is provided to cater for road transport deliveries, and a silica ground hopper is also incorporated from which the material is transferred to the kiln bunkers by vibrating feeders and conveyors.

Kiln storage capacity is provided for approximately one day's supply of coal and ore and one week's supply of the fluxing materials. The concrete kiln bunkers are divided into 25 sections, five sections (one per kiln and one spare) being available for each material. Kiln feed conveyors operate beneath the bunkers and weighfeeders are installed to weigh and proportion each material accurately. A reversible conveyor can feed raw material to any kiln system from the spare bunkers.



Wagon tippler serving the raw materials plant.

PREREDUCTION PLANT

The plant consists of four prereduction kilns designed to prereduce iron ore to an oxidation degree of 55%. It is rated for a maximum output of 1,180,000tons/year, which comprises prereduced iron ore, char, calcined lime, dolomite, and silica. These materials are discharged hot from each kiln into a storage bunker from whence they are handled by a hot charge transport system to the submerged arc smelting furnaces.

Refractory lined throughout, the four kilns are each 197ft (60m) long, 13ft 1½in (4m) id, constructed in boiler plate 1¼in (31mm) thick over the main shell length, but reinforced to 2⅜in (60mm) thick under the running tyre and gear rim sections. Each kiln is provided with two running tyres of cast steel 17ft 7in (5·3m) od × 2ft 7½in (0·8m) wide welded to the reinforced sections of the kiln shell.

Each tyre is carried on a roller station, each station comprising two cast-steel rollers 4ft 9in (1·4m) dia × 2ft 9⅞ in (0·85m) wide mounted in roller bearings. The roller stations are supported on concrete pedestals arranged to allow the kiln a slope from the feed to the discharge end of 3·5% (2°). The rear or high end roller station incorporates a thrust roller arrangement with two cast-steel rollers 3ft 3⅜in (1·0m) dia × 6¼in (0·15m) wide mounted in roller bearings and designed to run on the side faces of the rear kiln tyre.

The rear support pedestal also carries the kiln main and emergency drives. The main drive provides kiln rotation over the range of 0·4 to 1·2 rev/min, and is effected by two 95hp 440V thyristor controlled dc motors via two triple stage helical reduction gearboxes, each coupled to a spur pinion.

The emergency drive arrangement consists of two 20hp ac motors powered by an automatic starting 280kW emergency diesel alternator. In addition, the 95hp (71kW) motors can be fed from the main 1500kW diesel alternator.

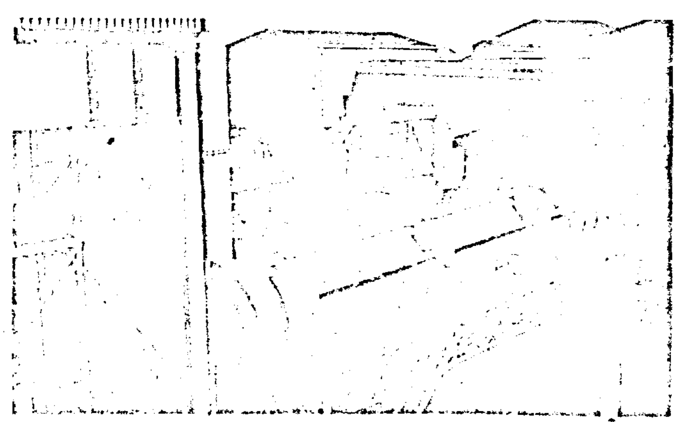
The raw materials to be reduced are fed into each kiln via a double pendulum flap valve to prevent ingress of air into the kiln.

Firing is accomplished in a co-current manner be means of pulverised fuel produced in two 7tons/h capacity ball mills located in the central pulverised fuel plant. The pulverised fuel is distributed pneumatically to storage hoppers at the kiln heads from which point it is fed again pneumatically to a lance, stabilised by supplementary gas, which projects inside the kiln feed end.

Each kiln is provided with special inlet and outlet hoods mounted on wheels to allow for kiln expansion. The hoods are refractory lined and incorporate special slip ring sealing devices between the rotating kiln shell and the stationary hoods to prevent ingress of excess air.

The main combustion air is introduced into the kiln via 10 air pipes of heat resisting steel, arranged along the kiln length and projecting through the material bed inside the kiln. Each pipe is connected to an air fan, mounted on the outside of the kiln shell, and incorporates a manually controlled damper to adjust the amount of air at each position. Control is thus exercised over the temperature profile in the kiln while maintaining the necessary reducing conditions inside the kiln.

One of the prereduction kilns.



The waste gases generated in each kiln are extracted by a waste-gas fan driven by a 450hp (336kW) ac motor, cooled in a spray tower and then further cleaned in a bank of multiclones before discharging to the atmosphere. The gas duct arrangement between kiln and spray tower incorporates a flap valve, which automatically opens in emergencies to emit the gases direct to atmosphere. Sludge from the spray tower and dry fines from the multiclones are mixed and pumped as slurry to a thickener and thence to a slimes dam, from which the water is recovered for further use.

The reduction plant is fully instrumented and the control pulpits are arranged one to each pair of kilns. The pulpits also house the weigh feeder control equipment, thus control of raw materials feed to the kilns is exercised from these positions.

HOT CHARGE HANDLING

Refractory-lined containers operating in a lift shaft are provided to transport the charge, at about 1050°C, from the kilns to the 24 storage hoppers at the high level in the smelter plant. Electrically operated charging cars and transfer cars permit distribution of the hot charge to the refractory-lined insulated hopper. The covers of these hoppers are removed to allow the transport container to deliver its contents into the hopper from which the charge is fed into the furnace by refractory lined gravity chutes, so keeping heat losses to a minimum.

THE SMELTING FURNACE

The final reduction takes place in "Elkem" electric smelting furnaces with coke formed from the coal in the kiln as a reductant.

Each furnace is designed to tap an average of about 60tons of metal into one 80ton capacity ladle and 45tons of slag into two 30ton capacity slag pots. Iron and slag are tapped simultaneously and separated by the dam and skimmer method. Both the ladles and the pots are transported in rail-mounted carriages.

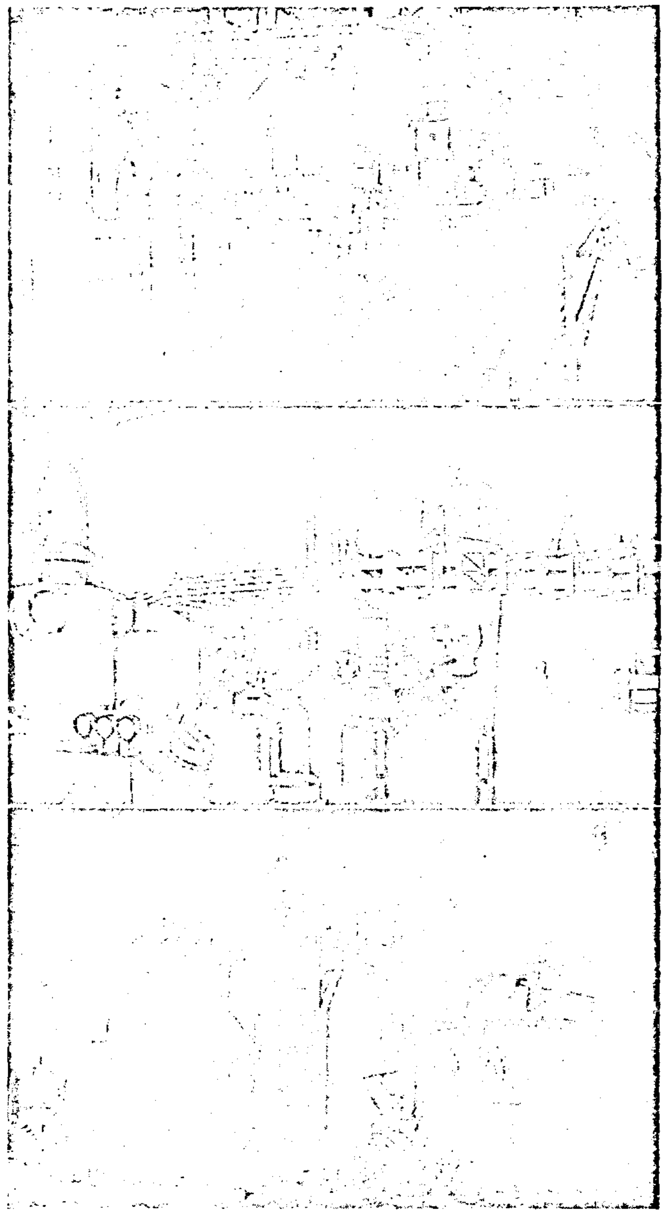
The four furnaces are of the stationary, covered type. Each furnace has a transformer capacity of 30,000kVA and is designed for a yearly production of 120,000tons. A furnace comprises mainly furnace pot with cover and charging shafts, overhead charge hoppers, and feed chutes as mentioned above. Electric energy is supplied to the furnace from transformers through heavy, interleaved bus bars and three continuous Søderberg electrodes.

The furnace shell has a diameter of about 46ft (14m). The cover, which has a corresponding span, consists basically of refractory bricks fitted in between rigid water-cooled beams and frames. The space and area of each individual cover section is thus of moderate dimensions, and the risk of damage correspondingly reduced.

The total weight of each of the selfbaking Søderberg electrodes and its equipment is about 60tons. The electrodes are suspended from the building by hydraulic hoists, and the function of these hoists is to regulate the penetration of the electrodes in the furnace charge.

An electrode regulator, which works on the principle of either constant electrode current or constant impedance, according to choice, measures the electrical parameters in the furnace and compares and adjusts these to preset values. As the resistance of the furnace charge changes, the electrode regulators automatically regulate the penetration of the electrodes so as to maintain constant electrode current or impedance. Regulation of the smelting process is, in other words, obtained through continuous control of the electrode penetration in the furnace charge.

Each furnace is provided with two tapholes, two independent launder systems, and a combined, pneumatically



The ironmaking plant: Top—the upper level where the hot product from the prereduction kiln is fed to the "Elkem" furnaces via the charging shafts in the foreground. Centre—the intermediate level showing furnace cover, charging tubes and shafts, smoke hood, and cooling water supply. Bottom—hot metal and slag being tapped simultaneously from one of the furnaces.

operated drill, and taphole gun for opening and plugging of tapholes.

Gases generated in the furnaces are cleaned in two-stage Venturi scrubbers before being stored in a gasholder for distribution, via a mains system of 1¼miles (2km), for heating of the rotary prereduction kilns and for general heating purposes within the ironmaking plant, steelplant, and rolling mill. Whereas a furnace normally produces about 176,550ncu ft/h (5000nm³/h) of gas, each furnace is equipped with two gas cleaning plants, each of 141,240ncu ft/h (4000nm³/h) capacity. So, on reduced furnace load, one Venturi unit has ample capacity to collect the gases when the other unit is shut down for cleaning.

The cooling water for furnace shell, cover, and electrodes is supplied from a central pumping and water treatment station, which also serves the kiln and other water requirements inside the pig-iron plant. Total demand for water is 8·5million gal/day (38·6million litres/day) out of which some 7·5million gal (34million litres) is continuously recirculated.

INSTRUMENTATION

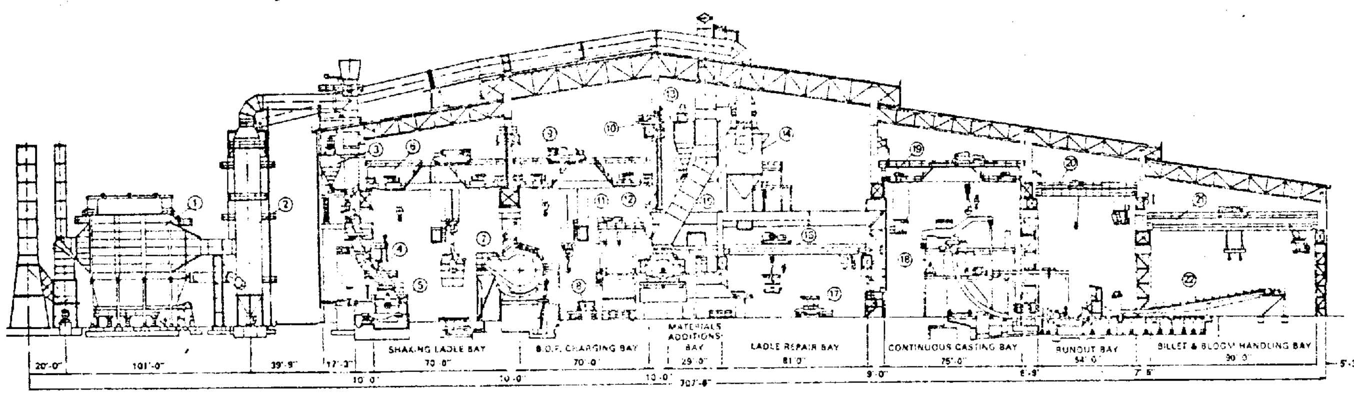
Comprehensive instrumentation is provided for both the kilns and smelters, and extensive use is made of mimic panels and grouped controls to permit centralised remote control of the operating units. Forty different variable parameters are indicated and/or recorded for each kiln/smelter process combination including the flows, pressures, and temperatures of all systems and material feed rates. Extensive interlocking and alarm systems are incorporated to ensure safe operation of the plant.

Steelmaking and Continuous Casting Plants

THE STEELMAKING AREA comprises basically the hot metal mixers, shaking ladles, basic oxygen furnaces, and continuous casting plant. The steelplant building consists of eight parallel bays; **Fig5**, which is a typical section through the bays, also shows some of the main plant items.

MIXERS

Liquid iron from the ironplant, which contains about 4% carbon and 1·35% vanadium, is stored in two 800ton capacity gas-fired inactive mixers. The mixers are so positioned that iron can be charged into them from the south side and discharged to the north into 60ton capacity shaking ladles suspended from the 180ton capacity crane serving the shaking ladle bay. These mixers have been found difficult to operate due to viscous slags being formed when titanium oxide is precipitated out.



KEY: 1—Electrostatic precipitators; 2—conditioning towers; 3—material bunkers; 4—fume hood for shaking ladle; 5—shaking ladle emplacement; 6—180ton ladle crane; 7—800ton inactive mixer; 8—slag pot transfer car; 9—180ton ladle crane; 10—lance carriage; 11—7/7ton scrap charging crane; 12—basic oxygen furnace; 13—materials bunker; 14—spark boxes; 15—furnace hood; 16—30ton ladle repair crane; 17—casting ladle transfer car; 18—continuous casting machine; 19—90ton ladle crane; 20—10ton maintenance crane; 21—15ton handling crane; 22—dummy bar parking ramp.

5 *Section through steelmaking plant.*

SHAKING LADLES

Two shaking ladle emplacements complete with twin-drive units, each employing a 100hp squirrel cage motor and induction coupling, are provided for imparting an oscillating motion to the liquid metal, the speed being controlled by the slip in the coupling.

A hydraulically operated pivotted water-cooled hood of double wall construction is provided to swing over each shaking ladle emplacement for directing fume and hot gases to a common conditioning tower and a dry electrostatic precipitator. The iron ore and fluxing materials required for the process are stored in bunkers at high level in the shaking ladle materials bay. The vanadium contained in the metal is removed by top oxygen blowing through water-cooled lances. It is oxidised to vanadium pentoxide, the important constituent of the slag.

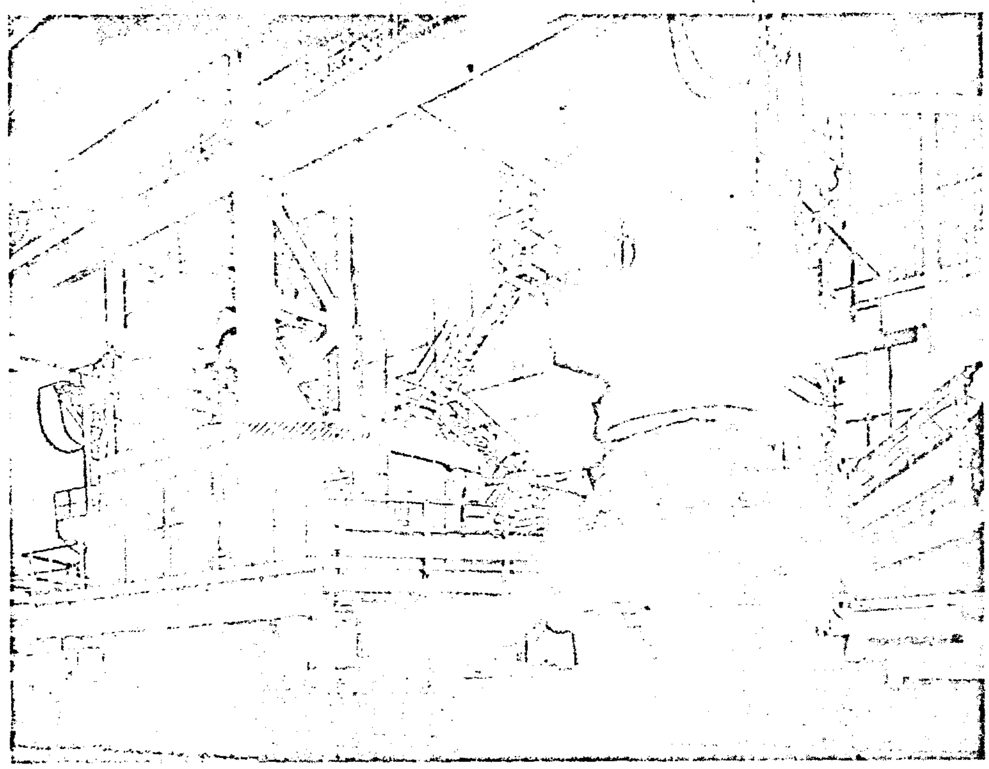
A separate area, which is served by a 10ton magnet crane, is allocated for scrap storage and preparation. Scrap weighing and scrap charging machines are installed for weighing and tipping scrap from pans into the shaking ladle. The scrap pan transfer feeds scrap to the BOF bay.

The shaking ladle transfer car carries the ladle of partially blown metal through to the BOF bay where two 180/50ton cranes are available for charging the metal to the two 60ton basic oxygen furnaces. Concrete compounds are provided for receiving the vanadium pentoxide slag from the shaking ladles.

In addition to the above equipment, a 60ton/h twin-strand pig-casting machine, complete with hydraulic wagon haulage system and Davit ladle tilter, is installed to the west of the steelplant. This is used for the casting of vanadium-free metal from the shaking ladles, though it can accept metal direct from the smelters. The plant is self-contained, including facilities for liming the moulds, water cooling the strands (and the wagon loads of pigs), and for gas preheating and drying of the moulds. The strands are 200ft (61m) long and speeds of 0 to 70ft/min (21m/min) are available, the two strands being independently controlled by MG sets.

BASIC OXYGEN FURNACES

There are two 60ton basic oxygen furnaces. These are equipped with membrane type water-cooled hoods which conduct the waste gases to spark boxes and thence to a common conditioning tower and a dry electrostatic

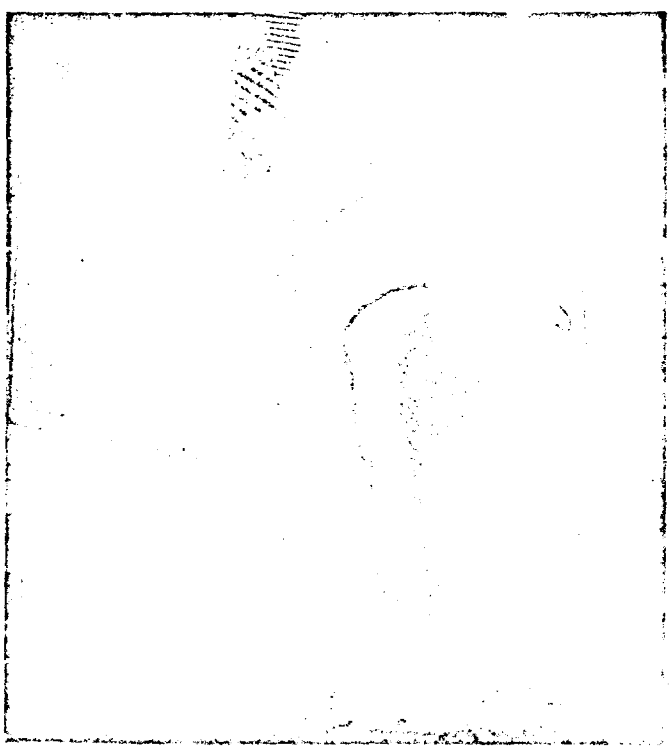


Molten iron in one of the shaking ladles being top blown with oxygen.

precipitator. The water in the hood systems is circulated by three pumps (one per hood and a common standby) to fan-cooled finned tube heat exchangers located to the east of the steelplant and thence back to the hood. A nitrogen pressurised water drum is included above each hood, the level being maintained automatically by pumps supplying demineralised water.

Twin oxygen lances are set above each BOF vessel on a high-level traversing carriage, so arranged that the operating lance can be withdrawn from the vessel, the carriage traversed, and the replacement lance lowered in a matter of seconds. Each lance is driven by a twin-speed motor driving a rope winch through gearboxes. A pneumatic lance clamp holds the lance when in the lowered position and oxygen can be blown at rates of up to 8000ncu ft (226ncu m)/min. The lances are water cooled by a closed circuit system using pumps and fan-cooled finned tube heat exchangers.

Deslagging area: the shaking ladle is being upended to remove the vanadium pentoxide-containing slag for subsequent sale.



Each BOF is driven by two 75hp (56kW) dc motors (each of which is capable of driving the vessel) with thyristor control from MG sets. Either set can be switched into the operating vessel.

An overhead bunker system provides flux additions and iron ore via vibrating feeders and weigh hoppers. A 7/7ton portal crane is mounted on the operating platform for charging scrap into the vessels.

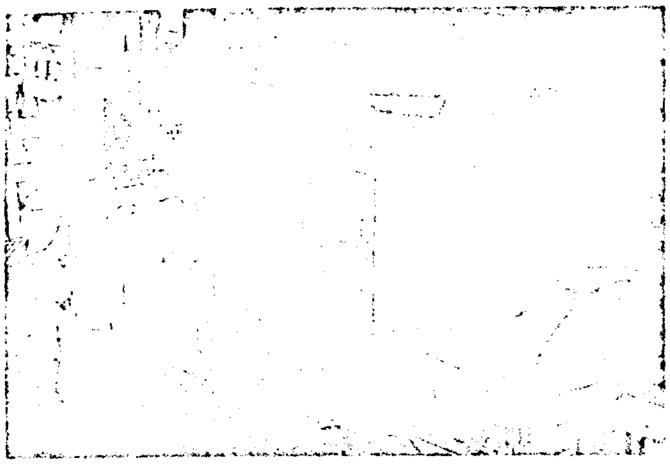
INSTRUMENTATION AND CONTROLS

Comprehensive instrumentation for shaking ladles and BOFs is provided in pulpits, one common to both shaking ladles and one common to both BOFs and set between them in each case on the operating platform. Oxygen integration and automatic cut-off facilities are included, together with digital lance height indication and indicators for flows, pressures, and temperatures of all systems. Hood water circuit mimics are included for the BOFs. Extensive interlocking and alarm systems are incorporated to ensure safe operation of the plant.

Under each vessel a slag pot and a casting ladle are each carried in electrically driven cars running on tracks leading across the ladle repair bay and into the continuous casting bay.

REPAIR BAY

The repair bay, with a concrete floor slab area of over 28,000sq ft (2600sq m), is serviced by two 30/10 cranes. In the repair bay the slag pots are emptied into concrete bunkers and the ladles and tundishes are prepared for use. Brick lining of the ladles is done in a 45ft × 14ft 9in × 11ft 6in (13·7m × 4·5m × 3·5m) deep pit serviced by a 2ton swinging jib crane. Tundishes are prepared in special



Blowing in progress on one of the two 60ton basic oxygen furnaces.

stands which act as jigs for the setting of the nozzle bricks. Gas-fired heaters with flame failure devices are used to dry and preheat both ladles and tundishes. The heaters are capable of heating the ladle lining to 1100°C in 12h, using "Elkem" gas. Preparation areas and electrically-heated drying ovens are provided for both ladle and tundish stopper rods.

CONTINUOUS CASTING

The casting area includes the continuous casting machines and a small emergency ingot casting floor. The total area is over 84,000sq ft (7800sq m) of which only 4000sq ft (372sq m) is reserved for ingot casting.

The continuous casting facilities, with an initial design output of 60tons/h comprise three machines. The first of these (**Fig6**), a four-strand bow-type caster of 32ft 10in (10·0m) casting radius, is designed to cast blooms of 5½in × 5½in (140mm × 140mm) and 8in × 8in (203mm × 203mm).

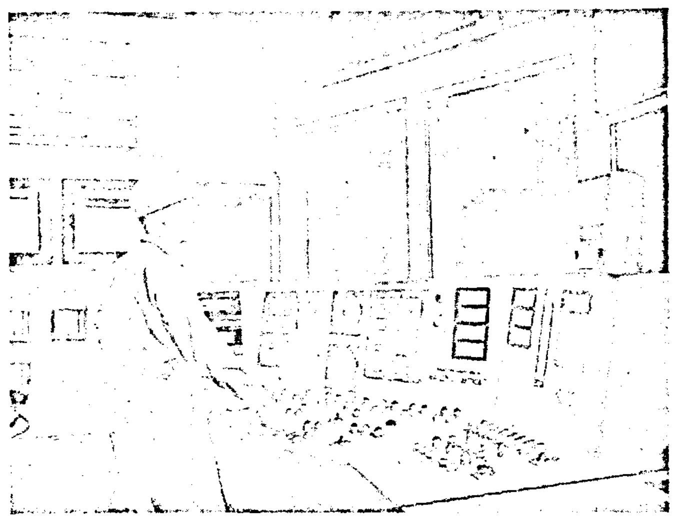
The other two machines are two-strand bow-type casters of 37ft 9in (11·5m) casting radius, designed to cast 12in × 10in (305mm × 254mm), 16in × 9in (406mm × 228mm), and 22in × 12in (558mm × 304mm) wide slabs. The rated capacity of the complete plant is 1100tons in 24h.

The machines extend through three bays, namely casting, run out, and ingot handling, with spans of 75ft (21·4m), 54ft (16·4m), and 90ft (27·5m), respectively.

The three casting machines accept 60ton heats from two BOF vessels. The casting programme covers structural and rail steels. Sequence casting of two heats is already standard practice and recently three heats have been continuously and consecutively cast on one machine.

The principal features of the casting plant are as follow. The casting bay is equipped with two 90/20ton overhead electrical travelling cranes, which are able to lift the steel ladles onto one of the two ladle cars.

Dual heat casting is carried out by the following procedure. Steel from a stoppered casting ladle held by a crane is cast first. When the casting ladle has been emptied, the ladle



Control room for basic oxygen furnaces.

is removed by crane. Meanwhile, another full ladle has been brought by the second crane to a ladle car, which is tracked over the casting machine while steel continues to be poured from the tundish. When the steel ladle is over the tundish, the second heat is poured.

The four-strand machine is equipped with straight moulds and the two two-strand machines with curved moulds. The two-strand machines however can also be converted to straight mould operation.

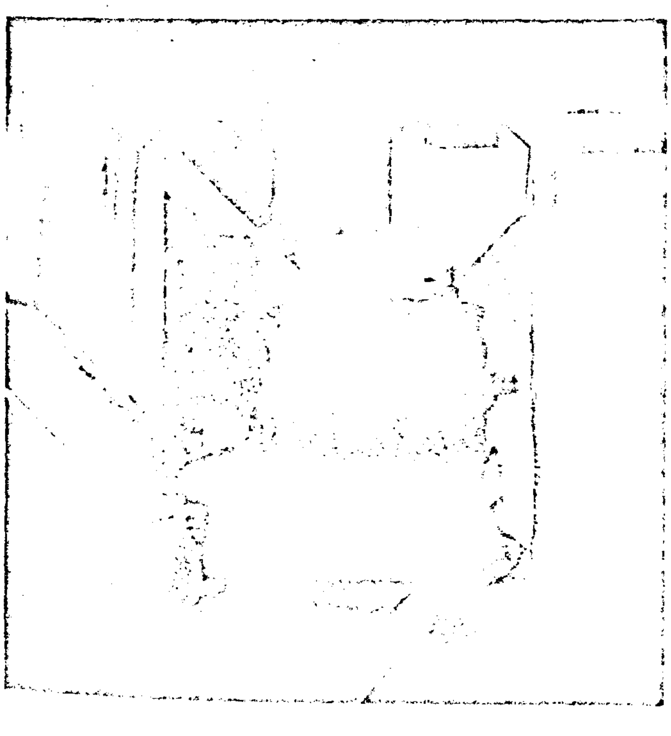
The roller apron frames of the four-strand caster are removed from the spray chamber on cars if the strand section has to be changed which calls for different roller aprons. The roller apron frames of the slab casters can be dismounted by crane after the moulds and the internal mould oscillator frame have been dismantled.

The guide frames of the four-strand machine are of water-cooled tubular steel construction. The guide roller frames of the slab machines are equipped with roller assemblies which can be detached from their frame and lowered with the aid of a changing rig. The roller journals are water cooled.

The straightening machine of the four-strand caster consists of a water-cooled frame, which extends across the four strands. The straightening rollers, which can be hydraulically raised and lowered, are mounted on the side of the frame.

The combined cooling water requirements can be 10,000-gal/min (45,460 litres/min) at pressures varying between 30 to 150 lbf/sq in (103,421·4N/m²). To provide this together with adequate standby facilities, 24 pumps with electrical drives totalling 2000hp (1491kW) are installed.

Tapping the BOF furnace.

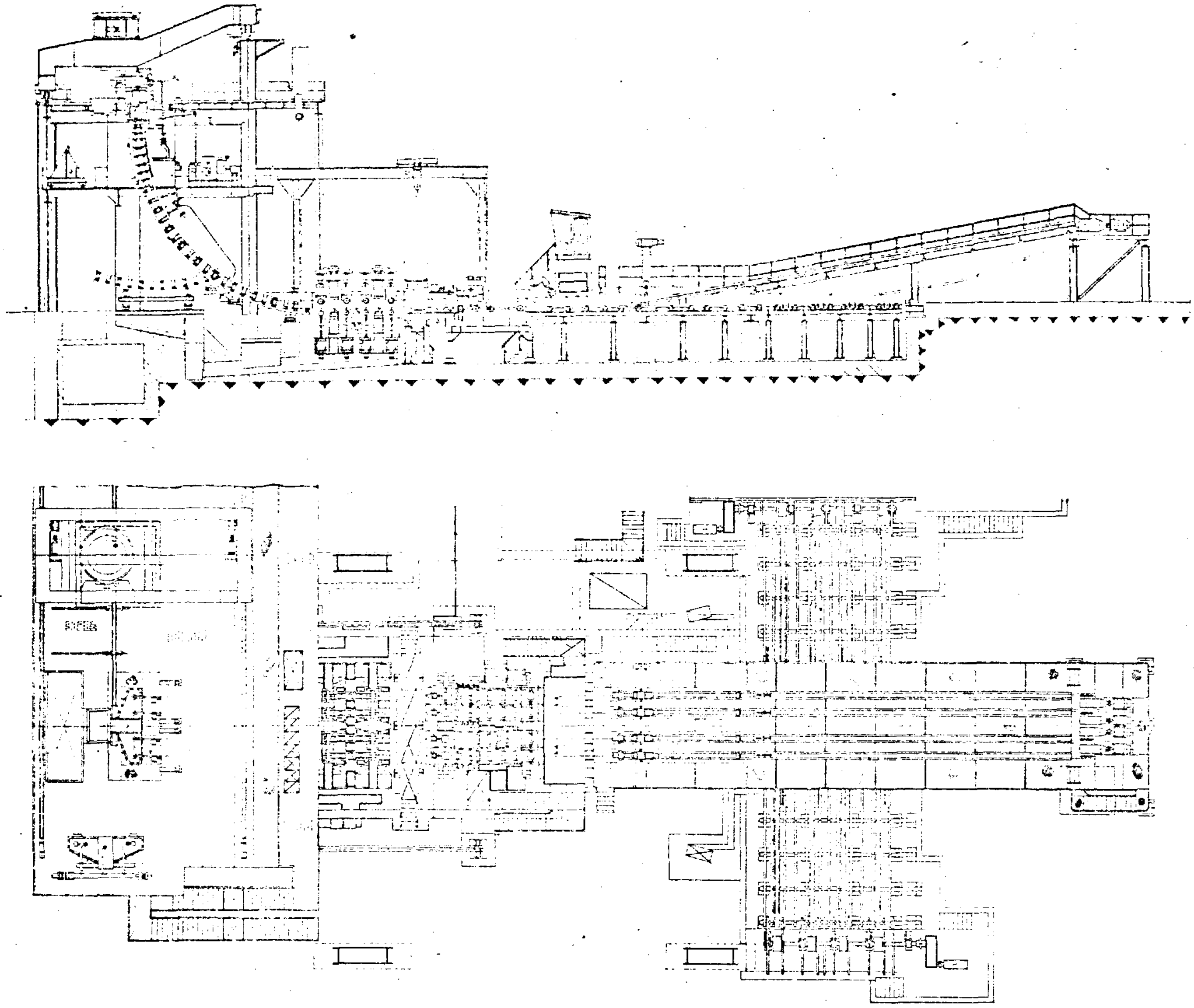


The dummy bars are stored on inclined ramps arranged above the run-out tables of the casting machines. The cast strands are cut by torch cutting machines to the desired ingot or bloom lengths.

The four-strand caster is equipped with two cooling beds. The cut blooms are stored on the right and left of the run-out tables. For removing cooled blooms from the cooling beds there are two 15ton magnet cranes.

The rollers of the run-out tables are individually driven. All the rollers are connected to a circulation lubrication system. A 10ton crane is provided for maintenance work in the run-out bay.

The continuously cast ingots or blooms are transported from the ingot handling bay to the rolling mill stockyard, via a weighbridge, on 60ton road trailers.



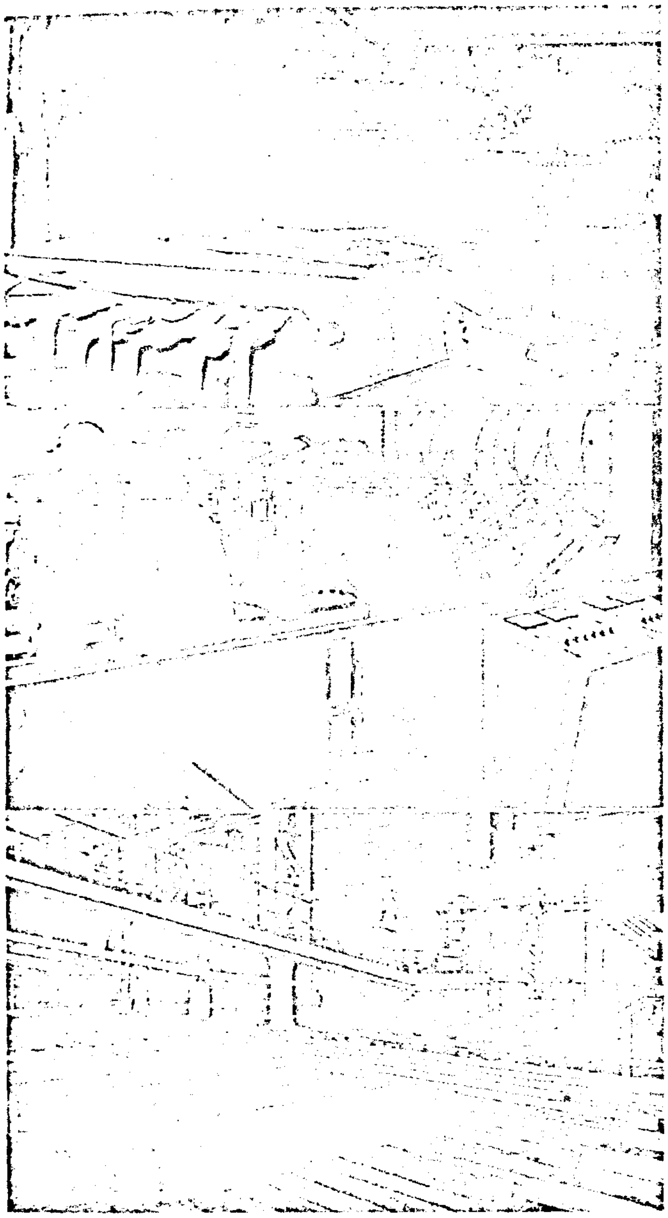
6 *Section and plan of No1 continuous casting machine*

Rolling Mills

THE ROLLING MILL COMPLEX, illustrated in **Fig7**, includes two walking beam furnaces for the reheating of continuously cast ingots, followed by rolling through the combination universal beam, rail and section mill, plus extensive finishing facilities designed for an initial annual output of approximately 300,000tons of finished product. The principal products will be universal beams and columns up to 18in × 7½in (460mm × 178mm) and 12in × 12in (300mm × 300mm), respectively, rails up to 115 lb/yd (56·6kg/m) and in lengths up to 120ft (36·5m) angles, channels, etc.

Should future markets produce an increase in demand for the larger sizes of universal beams the output of the mill will obviously be increased. To meet this increase, provision has been made in the mill layout for extra reheating and finishing facilities. Provision has also been made for the production of 8in to 22in (200mm to 550mm) wide universal plate, by the addition of a vertical edging stand at the universal roughing mill. The mill is also capable of rolling sheet piling, rounds, and special sections.

Four two-stage coal-fired gas producers supply 1,320,000cu ft/h of clean gas, sufficient to feed the two ingot reheat



The continuous casting plant: Top—teeming via tundish into moulds; Centre—hot strand emerging along guide frame to the straightening machine; Bottom—after torch-cutting to required length the ingots pass to the discharge area ready for despatch to rolling mill.

furnaces at full capacity. The two walking beam reheat furnaces, claimed to be the largest of their type in the world, are capable of a total rated output of 120tons/h. Each furnace has two hydraulically operated walking beams which can be controlled independently or in synchronism. The furnace is designed to reheat the whole range of ingot sizes, the maximum of which is 22in × 12in × 23ft (560mm × 300mm × 7m) long, to 1250°C.

The furnaces are 7·6m (25ft) wide and 35m (106ft) long. The choice of the walking beam system as compared to a pusher system ensures more careful handling of the charge, a reduced heating time, and minimal oxidation.

Four large electrical sub-stations house all the control gear for the main drives and mill auxiliaries. Two miles (3·2km) of underground cable tunnels carry a network of nearly 500 miles (800km) of control and power cables required for the electrical operation of the rolling mill.

The extensive mechanical services distribution system comprises water, compressed air, propane, oxygen, steam, and includes a water treatment and cooling plant.

The rolling mill is installed in a single building nearly 2000ft (610m) long with five bays covering a total area of 701,590sq ft (63,500sq m) served by eight electric overhead travelling cranes, six of which have magnet facilities.

The mill equipment consists of the following units. The 40in × 96in (1000mm × 2440mm) breakdown mill is powered by a 6250hp (4650kW) double armature dc motor, served by manipulators fitted with tilting fingers and followed by a 66in (1680mm) hot saw and bloom transfer car.

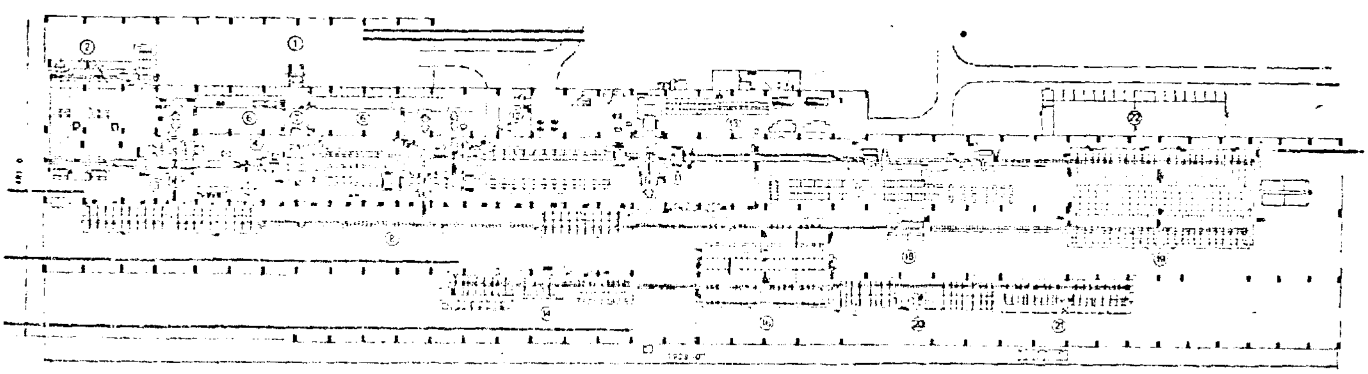
The 32in × 90in (820mm × 2280mm) structural roughing mill is powered by a 5125hp double armature dc motor. Parallel to the structural roughing mill is the universal roughing group comprising a 50in (1270mm) universal stand powered by a 6000hp (4470kW) double armature dc motor and a close coupled 33in (840mm) beam edging mill powered by a 1500hp (1120kW) single armature dc motor. The combination finishing mill, powered by a 3600hp (2680kW) single armature dc motor, achieves the final reduction and profile of the product. The finishing mill is designed to accept either 50in (1270mm) universal rolls or 32in × 96in (820mm × 2280mm) section rolls, and is equipped with a special duplex carriage type quick roll change rig.

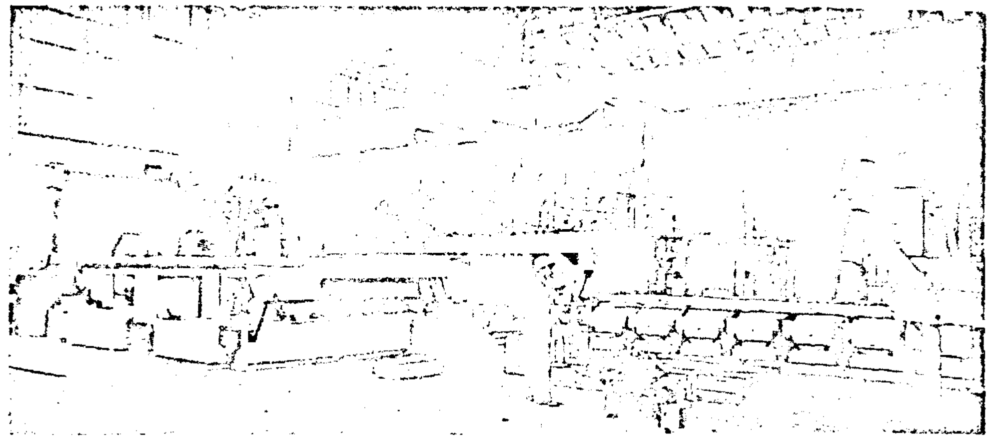
Automatic operation is applied to all mill stands. All mill drives are rectifier fed from the 33kV network via stepdown transformers and single anode, mercury arc, steel tank rectifiers. Each armature is electrically separate and is capable in the event of failure of one armature of driving the mill at full speed with half power.

The finishing equipment consists of a hot cut-up line with two walking beam type cooling banks, two roller straightening machines, section gag press, pilers, and rail finishing equipment. A cold saw and a high-speed friction

7 *Layout of the rolling mill plant.*

KEY: 1—Ingot storage bay; 2—walking beam furnace; 3—breakdown mill; 4—hot saw; 5—slab transfer; 6—No3 electrical sub-station; 7—supervisory room; 8—rail finishing line; 9—structural roughing line; 10—universal roughing group; 11—combination finishing mill; 12—local maintenance shop; 13—roll shop; 14—cold cut-up line; 15—roll storage; 16—transfer bays; 17—hot saws; 18—roller straighteners; 19—primary cooling banks; 20—gag press; 21—piling banks; 22—No4 electrical sub-station.





The walking beam reheating furnace.

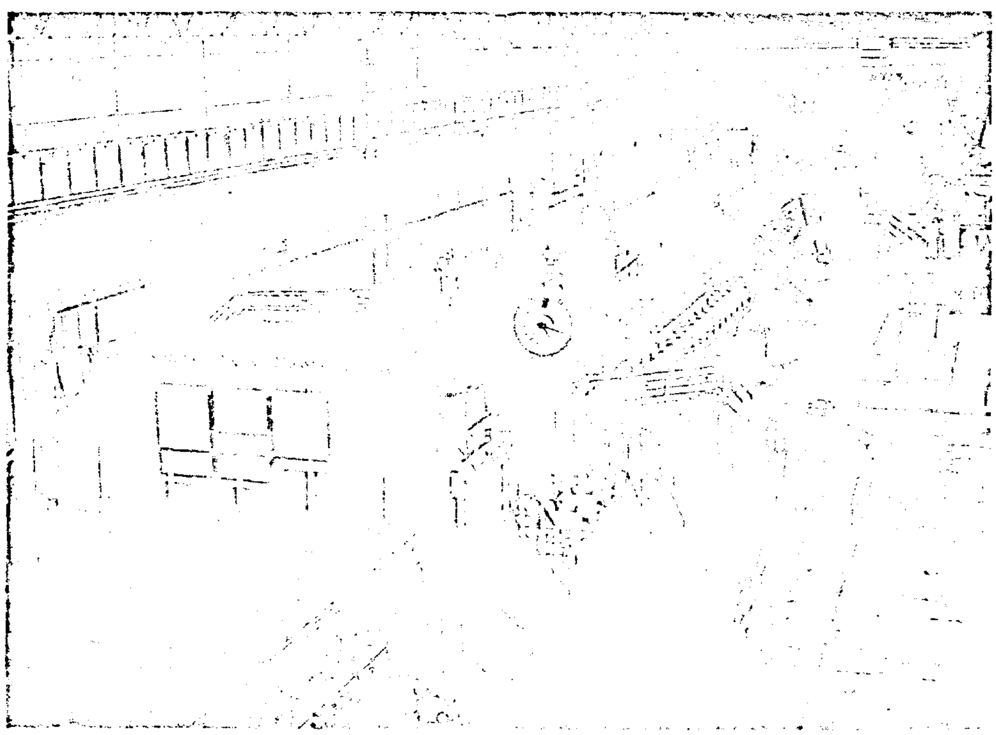
saw are also included in the section finishing line. The dc auxiliaries are thyristor fed from transformers coupled to the 33kV, 11kV, or 525V distribution systems. Roller tables in the area of the mill stands are all of the variable speed dc direct driven type. All finishing end roller tables are ac direct drives and fall into one of two categories, either constant speed fed at 12½ cycles from motor alternators or variable speed fed from frequency converters.

Ingots from the storage bay are loaded onto the ingot assembly bank, and from there, are fed singly onto the furnace entry table. Here they are weighed prior to charging into the furnace. After reheating to approximately 1250°C, the ingots are extracted singly from the furnace and transported by roller table to the breakdown mill. After rolling, blooms are either cut to length and transferred to the ingot yard or passed onto the roughing mill for further rolling. When producing sections and rails the bar is passed to the finishing mill, cut to length by the hot saws and delivered to one of the cooling banks. The maximum length of rail produced is 120ft (36·5m). If universal sections are being produced the bar is passed to the universal roughing group and then to the single pass finishing mill prior to cutting to length and delivery to the cooling banks. Analogue position control is applied to the 120ft (36·5m) wide walking beam cooling banks, to achieve variable stroke control.

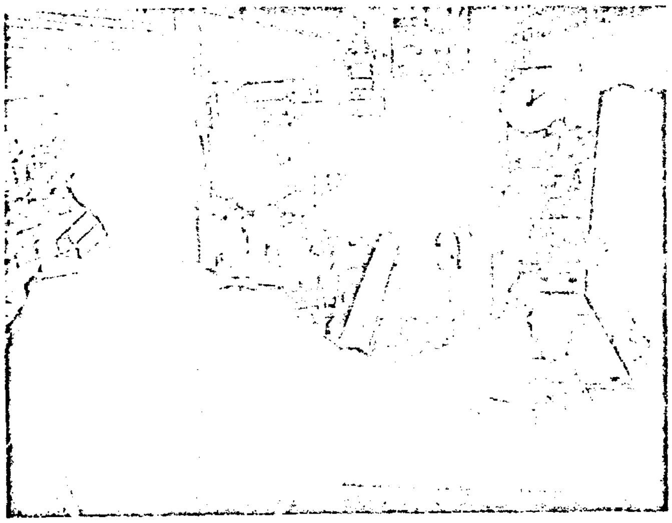
For rails requiring special slow cooling treatment (eg, for the special heavy duty requirements of South African railways) two specially designed slow cooling pits are provided. These pits are for treating about 7000tons/year of special quality 96 lb/yd (47·7kg/m) rails and a limited tonnage of 115 lb/yd (56·6kg/m) rails. The steel qualities are basically the higher carbon grades and those with a 1·8% and 2·0% manganese content.

The internal dimensions of the pits are 63ft (19·2m) long × 10ft (3m) wide × 8ft 6in (2·6m) deep and "Elkem" gas is used for preheating the pits to about 200°C in 3h to 4h. The rails are placed in the pits in layers and when the pit is full a steel cover is placed over the top by beam magnet. The rails are then left in the pit until the controlled slow cooling process is completed to the standard of the SAR specification.

After cooling all products are passed through the roller straighteners and then sent to either the rail or section finishing lines. The rail finishing equipment consists of a rail gag press and three rail ending and drilling machines. Sections are gag pressed if necessary then passed to the pilers or to the cold saws for the cutting to customer's requirement.

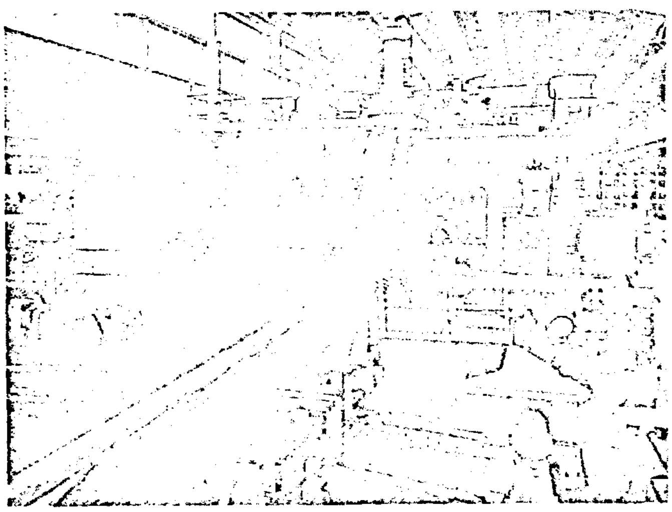


General view of the rolling mill with the 40in × 96in breakdown mill in the foreground.



Ingoing side of the roughing mill as viewed from the pulpit.

Universal roughing group, comprising a 50in universal stand together with a close coupled 33in beam edging mill engaged in the production of the first universal beams ever to be rolled in South Africa.



Ingoing side of the finishing mill.

Saw cutting of billets in the finishing line.

The movement of ingots through all stages of operation, from entry to the reheat furnaces to the cooling banks, is traced by cast tracking equipment, which is computer controlled and follows the bar along all the numerous different routes available.

Covered storage is provided for 202 pairs of rolls, which are redressed on two roll lathes and one profile lathe situated in the rolls shop, which also houses the chock change rig and guide and tackle making facilities.

Mechanical Services

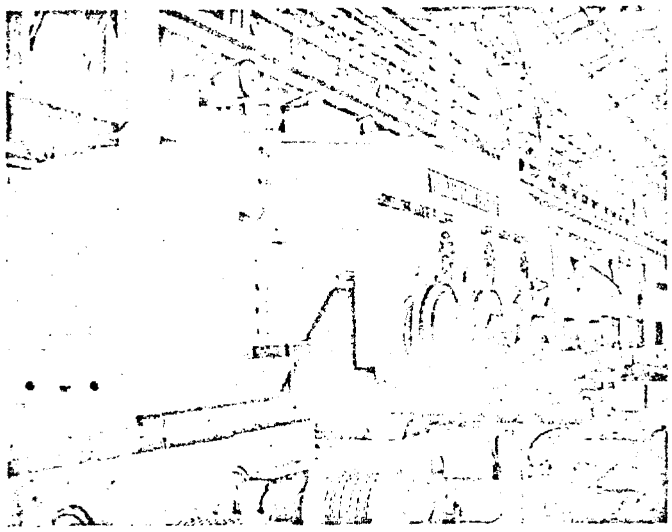
MECHANICAL SERVICES INCLUDE the provision and distribution of process, emergency, domestic, and demineralised water, steam, and compressed air; the distribution of smelter gas, oxygen, and propane and provision of fire protection and ventilation systems. The services are designed to ensure maximum economy in capital and operating costs. For example, slurry from the steelplant is clarified in the ironworks where the clean water is re-used, and the purge from the producer gas plant cooling tower is taken to the mill scale flume.

WATER SUPPLY

Initially approximately 40million gal/day (182million litres/day) of water is required of which 93% is continuously recirculated and treated. Raw water in which the total suspended solids may vary up to 1100ppm is brought from Witbank through a 20in (500mm) gravity main, and after treatment in an 80ft (24m) dia clarifier the solids are reduced to 15ppm.

Treated water is stored in two 600,000gal (2,730,000 litre) reservoirs and distributed through a ring main, pressure being maintained by a balance tank on the treatment house. The capacity of the present plant is 2·9million gal/day (13·2million litres/day), which can be doubled by addition of another clarifier. The domestic water plant, consisting of sand filters and chlorine dosing, has a capacity of 230,000gal/day (1,050,000 litres/day) and this water is pumped to a 100,000gal (454,600litre) capacity balance tank 105ft (32m) in height, from which it is distributed round the plant.

Demineralised water is provided from two sand filters and three mixed bed units designed for manual regeneration. The plant has a capacity of 100,000gal/day (454,600 litres/



Universal beams passing through straightener in the finishing line.

day) and demineralised water is stored in two 5000gal (22,700 litres) tanks on top of the steelplant building. Water from the Witbank main is used for fire protection and emergency cooling. Should the raw water supply fail, water can be drawn from the treated water reservoirs, the pressure being boosted by a pump. The water distribution is shown in Fig8.

GAS SUPPLY

The gas heating requirements of the plant (ie, for ingot heating, ladle drying, etc) are met by producer gas and the by-product smelting furnace "Elkem" gas. The gas producer plant consists of four two-stage pre-distillation units in parallel, each guaranteed to gasify 2·9tons of coal/h, giving a total output of about 1,300,000cu ft (36,800cu m) of gas/h and capable of more. Each of the four units is equipped with its own cleaning plant which de-tars, cools, and de-oils the gas.

The resultant clean gas has a gross calorific value of 165 to 180 Btu/cu ft (6150 to 6200kJ/cu m). The plant is well instrumented and its operation and response to sudden changes in quantity demand are virtually automatic. Coal and ash handling are mechanised and the only manual work required is the poking and trimming of the fire bed. The producer gas is used either alone or mixed with "Elkem" gas. The plant for mixing the two gases to a predetermined Wobbe index to suit the availability of the "Elkem" gas is controlled from a central panel.

Gas from the electric smelters is taken through a 40in (100mm) main to a 1¼ million cu ft (35,400cu m) gas holder from where it is distributed to the ironplant, steelplant, and rolling mill.

STEAM SUPPLY

The steam-raising plant and boilerhouse, which was installed by John Thompson Africa (Pty), of the John Thompson group, comprises two shell boilers of the semi wetback type for producing saturated steam at 150 lbf/sq in ($10{\cdot}3 \times 10^5 N/m^2$). The steam is used for bar descaling and oil heating in the rolling mill, gas main purging, pig caster mould cleaning, and as make-up for coal gasification in the gas producers.

Maximum evaporation of 6500 lb/h (2940kg/h) from feed at 50°F is achieved from each boiler when firing tar fuel, but "Elkem" gas can also be fired and provision is made for the two fuels to be fired simultaneously. Hamworthy rotary cup burners are fitted to the boilers.

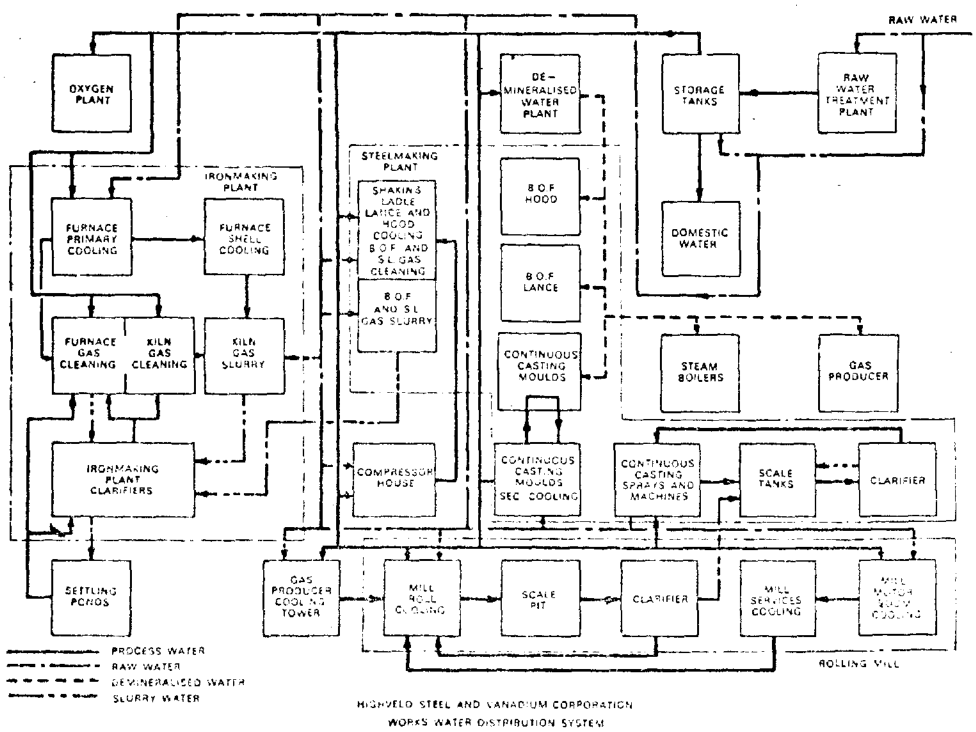
COMPRESSED-AIR SUPPLY

A centralised compressed-air generating station is installed comprising three two-stage reciprocating compressors each rated at 2000cu ft/min (56·5cu m/min) at 100 lbf/sq in ($6{\cdot}9 \times 10^5 N/m^2$) to provide all the compressed-air requirements of the works.

PROPANE AND OXYGEN SUPPLIES

Liquid propane is stored on site in two tanks of 5000 and 10,000gal (22,700 and 45,460 litres) capacity from where

8 *Water distribution system.*



it is evaporated and distributed around the works. Oxygen delivered from the 150tons/day tonnage plant outside the plant perimeter is stored in five gaseous storage tanks at a pressure of 600 lb/sq in each with a volume of 1900cu ft (54cu m). In addition, a liquid storage of 1000tons is maintained at the tonnage plant to ensure supplies during maintenance shut downs of this plant.

FIRE PROTECTION

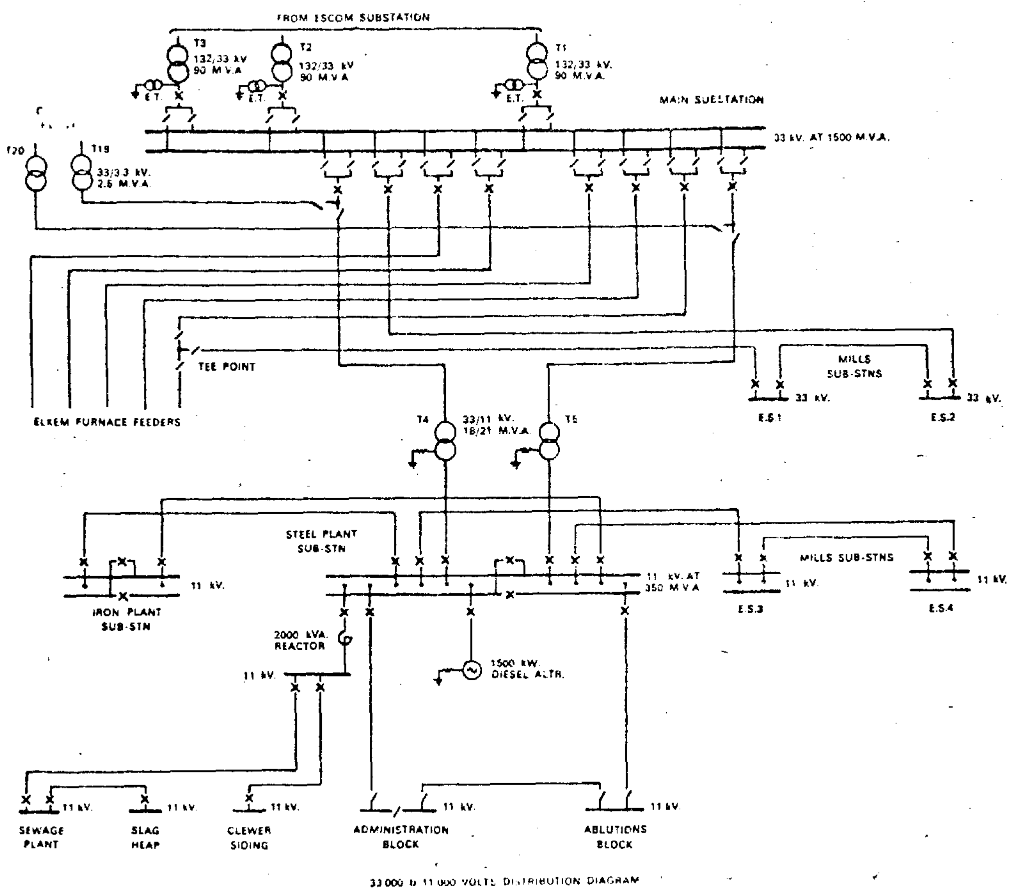
Apart from fire hydrants and hand appliances, fire protection consists of carbon dioxide installations in the transformer pens and sub-stations and water emulsifier systems in cable tunnels and underground oil cellars where carbon dioxide would be potentially dangerous.

VENTILATION

All contactor rooms, capacitor rooms, control pulpits, and underground cable tunnels are either ventilated or air conditioned and, where necessary, heated.

PIPEWORK

In all, 50 miles (80km) of pipework weighing 7100tons are supported on 750tons of trestles; 95% of this was fabricated, erected, tested, and commissioned within 12 months. As far as possible welded joints are used and X-rayed to standards laid down in APL 1104. Where temperature ranges are large, flexibility analysis and anchor loads were calculated on a computer to give optimum pipe thickness and anchor stresses.



9 *High voltage distribution system.*

Electrical Services

POWER IS TAKEN FROM two Electricity Supply Commission (ESCOM) 90MVA transformers, which provide a 33,000V 50 cycle supply to the main sub-station. A third standby transformer is installed. The works demand, which will be of the order of 120MW, is about the same as that of Singapore. Main distribution is at 33,000V with sub-distribution at 11,000V and 525V, a 380V four-wire system being provided mainly for lighting. In all, there are 23 sub-stations, 36 miles (58km) of power distribution, and 18 miles (129km) of supervisory and pilot cabling installed. Fig9 shows the high voltage distribution.

The main 33,000V sub-station adjoins the ESCOM sub-station and is separated from the works by the Pretoria/Witbank road. This sub-station contains eight double busbar circuits supplying the electric smelter furnaces, the steelplant, oxygen plant, and the rolling mills. These supplies are controlled by air-blast breakers, each in a separate cubicle.

Calculations showed that underground cables would require extensive excavations to obtain the necessary wide spacing between the feeder cables for heat dissipation if cables were not to be uneconomically large. It was undesirable to put these cables overhead across the main road, hence the solution was to construct a tunnel some 1000yd (914m) long between the main and ironplant sub-stations. The cables are oil filled, and the tunnel which is force ventilated incorporates a fire protection system. From the ironplant, cables are run on a services gantry to the steelplant and rolling mill areas.

The 11,000V system is supplied through two 18/21 MVA transformers located at the steelplant sub-station and is controlled by a double busbar oil circuit breaker switchboards at this point, at the ironplant, and at the rolling mills. A 1500kW 11kV diesel alternator supplies emergency power to essential equipment such as water-cooling pumps and emergency lighting. A 280kW diesel alternator supplies emergency power at 525V to the rotary kilns.

CONTROL CENTRE

A central control room in the rolling mills houses the supervisory control and alarm panels. Supervisory control is provided for all mills supplies, the 33,000V switchgear in the main sub-station, the incoming 11,000V circuit breakers in the ironplant and steelplant sub-stations, bus section switches, bus coupler, and the 1500kW emergency diesel alternator set.

Remote tripping from the control room is available on all circuits indicated there. Remote closing is restricted to those circuits which are not controlled from a local desk or pulpit. Certain critical distribution alarms, such as "low oil pressure in 33kV cables", are monitored directly in the control room. Other alarms are monitored on distribution alarm panels in major sub-stations and relayed to the control room as a sub-station fault. Plant alarms are monitored locally, but so arranged that should the alarm not be accepted within a predetermined time a general plant alarm is transmitted to the control room.

LIGHTING

Lighting is provided over conveyors, in sub-stations, and offices by fluorescent tubes. Internal high bay lighting in the main plant areas is from reflectorised mercury vapour lamps giving a lighting intensity of 15 to 25 lumens/sq ft (160 to 270 lm/m^2) depending on the operational requirements. For each point source a cluster of three fittings are connected to give a balanced load, thus reducing the stroboscopic effect. Emergency lighting is provided by tungsten lamps, which give an immediate light source when power is switched on. Power for lighting is supplied from 11,000/380V transformers, thus reducing the switching effects on the mercury vapour lamp from the utility 525V system.

COMMUNICATIONS

There are four types of communications systems. For internal and external communications, the works are served by 15 exchange lines into a 400 line PABX telephone exchange. Speaker microphone systems are installed in production areas for "talk back" communication, and, for hailing purposes only, in material handling areas. Carrier frequency inductive loop systems are used in the steelplant for crane to ground communication. Locomotives and mobile road transport are fitted with two-way radio giving communication with central transport control.

Central Services

THE CENTRAL ENGINEERING WORKSHOPS consist of departments for machining, fitting and fabrication and for maintenance and repair of road vehicles, electrical plant, locomotives, and instruments. The workshops are divided into five main bays, each 60ft (18·3m) wide × 210/270ft (64/82m) long, plus two smaller bays, giving a totally enclosed area of 82,000sq ft (7,630sq m). Each main bay has a heavy vehicle south entrance and a linking rail track at the north end of the workshops.

The 900tons of structural steelwork are clad with standard 22g steel and translucent sheeting, with the gantries supporting four electric overhead travelling cranes, one 20ton in the fitting bay and a 10ton in each of the machining, fabrication, and electrical/locomotive repair bays, respectively.

More than 90 machine tools have been installed for all maintenance and rectification work. In addition, an assembly/welding jig is used for the production of electrode casings for the smelter furnaces in the ironplant.

The central facilities area also include the oil and lubrication stores for bulk and barrel storage of oils; ferro-alloy stores; brick stores; and two general stores buildings giving, in total, a floor area of 53,500sq ft (4830sq m).

A central laboratory provides facilities for various departments of the plant for physical testing and chemical analysis of raw materials, hot metal, steel, slags, fuel, water, and refractories. It is equipped with the most up to date analytical equipment, particular emphasis being placed on the speed and accuracy of reporting—considered essential with the modern high rate iron and steel making processes. Two direct reading spectrometers, complete with computers, have been supplied to give rapid digital print-out of analytical results for metals and slags. A pneumatic tube sample transfer system is provided between the laboratory and outstations located in the ironplant and steelplant for despatch of samples requiring fast routine analysis. The analytical data are transmitted from the laboratory directly to the operator in charge of the particular process via automatic teleprinters located in the laboratory and in the operating pulpits.

Commissioning and Operational Performance

IN JANUARY 1965 A START-UP and commissioning programme was drawn up for the main areas of the plant, which at that time was based on a three-unit smelter. This envisaged ironmaking starting in April 1968, vanadium slag production in mid May, steelmaking in July and continuous casting in August 1968. The rolling mill was to be fully commissioned on continuously cast slabs over the period September to December 1968.

Although it was decided in June 1965 to add a fourth kiln and smelter the overall commissioning target date was not extended. In the event, the target dates were bettered or met, though significant tonnages of finished sections and beams were not produced until the first quarter of 1969.

Significant dates were as follow:—

February 26 1968 — first hot metal tapped from No1 smelter.

April 1968 — first vanadium slag produced in shaking ladle.

July 1968 — steelmaking and continuous casting commenced.

August 1968 — mill reheat furnaces, gas producers, and break-down stand of mill in operation. The first billets were rolled from continuously cast ingots on August 21 1968.

October 1968 — universal rougher and combination finishing stands commissioned and first universal beams rolled.

By the end of 1968 the iron and steel plants were fully commissioned and operating on the normal three-shift basis. The mill was operating on a two-shift basis while operators for the third shift were being trained and the finishing end of the mill was being commissioned. By the year end a large proportion of the product range had been trial rolled.

At the end of the financial year June 1969 iron output had reached 74% of rated capacity, steel output 56%, and in July 1969 the rolling mill, commissioned in October 1968, produced finished sections equivalent to 46% of rated capacity. During the year ended June 1969 some 15,000-tons of vanadium slag were produced for shipment to overseas customers.

During the current year production in all divisions has progressively increased.

As the plant was commissioned some problems arose. Many of these were due to inexperience in operation, some were due to minor faulty design and in other cases the selection of materials of construction proved wrong.

In the iron plant vanadium in the hot metal has not yet reached the level of recovery predicted from the pilot plant operations. Kiln availability has been lower than anticipated due to premature failure of the stainless steel air pipes and some refractory problems. Recent work indicates promise that both of these problems will shortly be solved. Probably due to the Ti content of the hot metal, which is 0·25 to 0·30%, considerable skulling of Kling ladles takes place between the iron and steel plants. This amounts to 2 to 3% of the total iron make. While this is recovered on deskulling of the ladles and returned as coolant through the shaking ladle operation it does present an unexpected labour demand. This same skulling problem persists through to the 800ton mixers and for this reason these have been cut out of the circuit. Hot metal from the ironplant is now charged directly into the shaking ladles in the steelplant.

In the steelplant the shaking ladle operation for the recovery of vanadium slag has operated very satisfactorily and mechanically has given no problems and the slag has been well received in overseas markets.

Steelmaking in the basic oxygen furnaces has been successful. Initially poor lining life on imported tar dolomite linings was a problem, but locally produced tar magnesite linings are now giving lives of 500 to 550 heats.

Continuous casting has posed few problems. After steelmaking commenced only four heats were conventionally cast into ingots. The fifth heat was successfully cast in the No2 continuous casting machine fitted with 16in × 9in (406mm × 228mm) moulds. The incidence of break-outs has decreased as the operators have gained experience on the machines and the quality of the cast ingots has been excellent. In general, the larger ingot sizes in Nos2 and 3 machines have given less operational trouble than the 8in × 8in (203mm × 203mm) and 5½in × 5½in (140mm × 140mm) on the No1 machine. Sequence casting is now routine and up to five 65ton heats have been cast in one operation.

The rolling mill is highly automated both mechanically and electrically and has demanded very extensive training of both operational and maintenance staff. Roll-pass design has been successful for the whole product range and the upper size limit of universal column rolled has been extended from 10in to 12in (250mm to 300mm).

During the early commissioning stages the buoyant market for all steel products throughout the world proved highly advantageous in that when the production of finished products was still low, surplus steel make was disposed of in both the local and overseas markets as rolled or continuously cast blooms and billets. The Highveld universal beams and columns have been very well received in overseas markets and local demand is growing at a satisfactory rate.

At the present time all the faults found during commissioning have been clearly delineated and most have been solved. Outputs of hot metal, steel and mill products are now more or less in balance and it is anticipated that overall rated plant capacity as planned will be achieved in the third year of operation.

LIST OF CONTRACTORS

DAVY AND UNITED Engineering Company, Sheffield, which was commissioned in January 1965 to design the plant, was also appointed as engineer, agent, and supervisor on the site for the building and commissioning of the plant. (Note: within the Davy-Ashmore Group the overall engineering of complete plants for the iron and steel industries is now the responsibility of the Davy Construction Company).

This list covers the major contractors, but it is emphasised that numerous minor contractors not listed here also made an important contribution to the success of the project.

Absorbit (vibration isolation system); A E I Henley (Africa) Pty (cables and communication equipment); Acrow Engineers (Pty) (steel platforms, stores, racks, etc); African Oxygen (oxygen pressure control station); Edgar Allen & Company (South Africa) (Pty) (coal pulverising plant); Allgemeine Elektricitats Gesellschaft (rolling mill electrics); Armstrong Whitworth (mill rolls); ASEA Electric South Africa (Pty) (transformers and electrical equipment for hot charging); Ash Bros (Pty) (metering and load control equipment); Ashmore, Benson, Pease & Company (BOFs and hoods oxygen lances and lance handling equipment); W & T Avery (weighing equipment).

Bailey Meters & Controls Africa (Pty) (instrumentation for shaking ladle, BOF, and mixers); Thos Barlow & Sons (front end loaders, etc); Ed L Bateman (domestic water treatment); Belliss & Morcom (Southern Africa) (Pty) (compressors); Birwelco (BOF hoods and lance heat exchangers); Brightside Foundry (rolls); British Insulated Callender's Cables (SA) (Pty) (cables); Brown Boveri SA

(Pty) (33kV switchgear, ferro-manganese furnace); Burroughs Machines (calculating machines).

Caltex Oil (SA) (transformer oils); Claudgen (ladle and tundish stopper rod ovens); Coon & Cooper Refractories (Pty) (installation of refractories for pre-reduction kiln); Cosine Engineering Company (Pty) (raw materials handling buildings); Cranes South Africa (Pty) (burner muffle removal hoists, EOT cranes); Cullinan Refractories (refractories); Cutler Hammer Igranic (process water motor control gear, kiln motor control boards).

Davidson & Company (Africa) (Pty) (contactor, capacitor, and pulpit ventilation for iron and steel plants); Hubert Davies & Company (cranes); Davy-Ashmore SA (Pty) (gasholder, scrap charging machine, scrap pans, pig-casting machine); Davy and United Engineering Company (rolling mill); Demag Industrial Equipment (Pty) (mixer); Demag Stranggiess-Technik GmbH (continuous casting); Denver Machinery Company (sump pumps); Dorman Long (Africa) (buildings); Drury Wickman (chemical electro machining equipment); Dryden Engineering Company (Pty) (air receivers); Dunn's Locomotive & Boiler Works (Pty) (foundation grid for shaking ladle); Dunstan A S (Pty) (office building and canteen); Davy and United Roll Foundry (mill rolls).

Electrokemisk AS (furnaces); English Electric of South Africa (Pty) (emergency 1500kW generator).

Fenter (Africa) (Pty) (sawing and filing machine); Floggi Africa (Pty) (sub-station ceilings); Forest Engineering (Pty) (various machine tools); Foundation Contractors (Pty) (civil works); Fraser & Chalmers (SA) (Pty) (fabrication and erection of ironplant).

Garlicks Office Equipment Company (clocks and time recorders); Genaire (Pty) (air conditioning); General Erection Company (Pty) (fabrication and erection works services pipework); General Fire Appliances Company (Pty) (sub-station fire protection); Gesellschaft für Huttenwerksanlagen mbH (shaking ladle installation); Grosvenor Motors (transport).

Hawker Siddeley Brush (compressor motors); Head Wrightson & Company SA (Pty) (ladles, cars, slag pots); Head Wrightson Teesdale (shaking ladle hoods); Hilton-Barber S (Pty) (site levelling).

Inline Construction (refractories installation).

Jeffrey Manufacturing Company (Pty) (raw materials handling); Johnson & Phillips (SA) (Pty) (transformers, switchgear); Johnson Rolls (mill rolls).

George Kent (SA) (Pty) (gas control station instrumentation); Victor Kent (Pty) (diesel engine pumps and alternator); Koppel Engineering (machine tools); Krupp South Africa (Pty) (mill cranes); Kurosaki Yogyo (refractories for BOF furnace).

Laurence Scott & Electromotors (SA) (Pty) (roller table drives); Leyland Motor Corporation (Tvl) (vehicles, trailers, etc); Lodge Cottrell (Africa) (Pty) (gas cleaning); Luke & Spencer (pedestal grinding machine); Lurgi Gesellschaft für Chemie und Huttenwesen mbH (pre-reduction kilns and pilot plant).

Macnay (Tvl) (Pty) (fork-lift trucks); Mantel Bros (Pty) (carry loaders); Martin Engineering Company (raw materials handling and lighting installation); Maschinenfabrik Deutschland AG (roll lathes); Mather & Platt (SA) (Pty) (pumps and fire protection equipment); Midland Roll Makers (mill rolls); Minnesota Mining & Manufacturing Company (SA) (Pty) (microfilm unit); Mitchell Engineering (Pty) (wagon charger mule and tippler; Mitsubiski Shoji Kaisha (refractories for BOF furnaces); Herbert Morris SA (Pty) (truck off-loader crane).

National Trading Company (hot saw sharpening machine). Samuel Osborne (South Africa) (Pty) (scale grab); Otis Elevator Company (elevators).

Neville Payne (Pty) (alloy transfer skips); Permutit Company of South Africa (Pty) (water demineralisation plant); Thomas Perry (mill rolls); Phillips Industries SA (Pty) (external light fittings); Phillips Telecommunications (Pty) (works telephone exchange); Pirelli General Cable Works (cable); Premier Metal Company of South Africa (Pty) (stores and workshop steel buildings); Pye Telecommunications (Pty) (locomotive radio telephone system).

Railway & Civil Engineering Construction (Pty) (railway sidings); Reunert & Lenz (hot charge equipment, locomotives, and transformers); A Reyrolle & Company (SA) (Pty) (switchgear); Rice & Diethelm (pumps); Rhokana Corporation (copper).

Safak (mill rolls); S A Pipe Company (Pty) (domestic water main); S A Scale Company (Pty) (weighbridges); Carl Schenck Mashinenfabrik GmbH (kiln raw material proportioning equipment); Siemens S A (Pty) (sample transfer system); Sparcatron Contelyt (electrolytic grinding machine); Spectro Services of South Africa (Pty) (spectrographic laboratory, physical testing laboratory); John G Stein & Company (refractories for No2 mixer); Stewarts and Lloyds of SA (valves and pipework); Switchcraft (lighting switchgear).

Taeuber & Corssen (Pty) (laboratory equipment); R B Tennent (mill rolls); John Thompson Africa (Pty) (boiler plant).

Paul Vahle S A (Pty) (Vahle conductors); VPC and Heurtey (Pty) (reheat furnaces and gas mixing station); Vereeniging Refractories (refractories); J H Vivian & Company (pumps).

Wellman-Incandescent Africa (Pty) (gas producer, drying-out and burning-in equipment); Allen West (Pty) (motor control gear); Alfred Wirth (straightener rolls).

UNION CARBIDE CORP.
Materials Systems Div.
Refractory Metals Center
Kokomo, Ind. 46901

UNITED MINERAL & CHEMICAL CORP.
129 Hudson St.
New York, N.Y. 10013

V

VAR-LAC-OID CHEMICAL CO.
666 S. Front St.
Elizabeth, N.J. 07202

W

WOLVERINE METAL CO.
6500 E. Robinwood Ave.
Detroit, Mich. 48234

WOLVERINE-SITKIN ALLOYS, INC.
50 Broadway
New York, N.Y. 10004

Z

MAX ZUCKERMAN & SONS, INC.
12 Music Fair Rd.
Owings Mills, Md. 21117

SAMUEL J. ZUCKERMAN, INC.
15 Mayflower Pl.
Floral Park, N.Y. 11001

Vanadium Products and Who Supplies Them:

ALLOYS

Atomergic Chemetals Co.
Belmont Smelting & Refining Works, Inc.
Bram Metallurgical Chemical Co.
Brandeis, Goldschmidt & Co., Inc.
Centrifugal Products, Inc.
Cometals, Inc.
Continental Ore Corp.
Kolon Trading Co., Inc.
Materials Research Corp.
Mercer Alloys Corp.
Morgan Chemicals, Inc.
Niagara Falls Metals & Minerals, Inc.
Lloyd M. Parkans Co.
RDG Alloys, Inc.
Reading Alloys, Inc.
Stalco International
Union Carbide Corp.
Mining & Metals Div.
Union Carbide Corp.
Materials Systems Div.
Var-Lac-Oid Chemical Co.

AMMONIUM METAVANADATE

Highveld Steel & Vanadium Corp., Ltd.
Morgan Chemicals Inc.
Union Carbide Corp., Mining & Metals Div.
Var-Lac-Oid Chemical Co.

BARS & RODS

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Kolon Trading Co., Inc.
Materials Research Corp.
Oregon Metallurgical Corp.
Poly Research Corp.
Union Carbide Corp., Materials Systems Div.
Var-Lac-Oid Chemical Co.

ELECTROREFINED SPONGE (99.9 percent plus)

Atomergic Chemetals Co.
Cometals, Inc.
Mercer Alloys Corp.
Poly Research Corp.
Stalco International

FERROVANADIUM

Alloychem, Inc.
Associated Metals & Minerals Corp.
Centrifugal Products, Inc.
Cometals, Inc.
Continental Ore Corp.
Derby & Co., Ltd.
Derby & Co., Ltd.
Derby Metals & Minerals, Ltd.
Foote Mineral Co.
Highveld Steel & Vanadium Corp., Ltd.
Mercer Alloys Corp.
The Metal Bank of America
The Ore & Chemical Corp.
Lloyd M. Parkans Co.
Parkans International, Inc.
RDG Alloys, Inc.
Reading Alloys, Inc.
Shieldalloy Corp.
Stainless Processing Co.
Stalco International
Steel Sales Corp.
Union Carbide Corp., Mining & Metals Div.
Var-Lac-Oid Chemical Co.
Max Zuckerman & Sons, Inc.

FOIL

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Oregon Metallurgical Corp.
Poly Research Corp.
Reactor Experiments, Inc.
Union Carbide Corp., Materials Systems Div.
Var-Lac-Oid Chemical Co.

GRANULES

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
The Metal Bank of America
Morgan Chemicals, Inc.
Poly Research Corp.
Union Carbide Corp., Materials Systems Div.
Var-Lac-Oid Chemical Co.

HIGH PURITY (99.5 percent plus)

Associated Metals & Minerals Corp.
Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Kolon Trading Co., Inc.
Materials Research Corp.
Mercer Alloys Corp.
Morgan Chemicals, Inc.
Niagara Falls Metals & Minerals, Inc.
Lloyd M. Parkans Co.
Poly Research Corp.
RDG Alloys, Inc.
Reactor Experiments, Inc.
Stalco International
Steel Sales Corp.
United Mineral & Chemical Corp.
Var-Lac-Oid Chemical Co.
Max Zuckerman & Sons, Inc.

INGOTS, BILLETS

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Kolon Trading Co., Inc.
Materials Research Corp.
The Metal Bank of America
Oregon Metallurgical Corp.
RDG Alloys, Inc.
Union Carbide Corp., Materials Systems Div.
Var-Lac-Oid Chemical Co.

PENTOXIDE V_2O_5

Alloychem, Inc.
American Metal Climax, Inc.
Associated Metals & Minerals Corp.
Bram Metallurgical Chemical Co.
Brandeis, Goldschmidt & Co., Inc.
Cometals, Inc.
Continental Ore Corp.
Derby & Co., Ltd.
Derby Metals & Minerals, Ltd.
Foote Mineral Co.
Highveld Steel & Vanadium Corp., Ltd.
Fred H. Lenway & Co., Inc.
Mercer Alloys Corp.
Metal Traders, Inc.
Morgan Chemicals, Inc.
The Ore & Chemical Corp.
Lloyd M. Parkans Co.
Parkans International, Inc.
Philipp Brothers, Div. of Engelhard Minerals & Chemical Corp.
Poly Research Corp.
Reading Alloys, Inc.
Skandia Metals Corp.
Stalco International
C. Tennant Sons & Co. of N.Y.
Union Carbide Corp., Mining & Metals Div.
United Mineral & Chemical Corp.
Var-Lac-Oid Chemical Co.
Max Zuckerman & Sons, Inc.

POWDER

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Continental Ore Corp.
Mercer Alloys Corp.
Morgan Chemicals, Inc.
Oregon Metallurgical Corp.
Poly Research Corp.
RDG Alloys, Inc.
Stalco International
Union Carbide Corp., Materials Systems Div.
Var-Lac-Oid Chemical Co.

RIBBON, STRIP

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Materials Research Corp.
Oregon Metallurgical Corp.
Poly Research Corp.
Union Carbide Corp., Materials Systems Div.
Var-Lac-Oid Chemical Co.

SHEET

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Cometals, Inc.
Kolon Trading Co., Inc.
Var-Lac-Oid Chemical Co.

TUBING

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
MEECO, A. Teledyne Co.
Var-Lac-Oid Chemical Co.

VANADIUM CHEMICALS

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Cometals, Inc.
Continental Ore Corp.
Foote Mineral Co.
Kolon Trading Co., Inc.
Morgan Chemicals, Inc.
Poly Research Corp.
RDG Alloys, Inc.
Union Carbide Corp., Mining & Metals Div.
Var-Lac-Oid Chemical Co.

WIRE & WIRE PRODUCTS

Atomergic Chemetals Co.
Bram Metallurgical Chemical Co.
Chicago Development Corp.
Cometals, Inc.
Materials Research Corp.
Oregon Metallurgical Corp.
Poly Research Corp.
Union Carbide Corp., Material Systems Div.
Var-Lac-Oid Chemical Co.

BUYERS OF SCRAP & RESIDUES

Centrifugal Products, Inc.
Cometals, Inc.
Continental Ore Corp.
Frankel Co., Inc.
Haley Smelting, Inc.
L. H. Hedger & Sons Metal Co.
Kolon Trading Co., Inc.
Legault Metals, Inc., Amos, Quebec
Legault Metal, Inc., Sts. Therese, Quebec
H.S. Mann Minerals & Metals Corp.
Mercer Alloys Corp.
The Metal Bank of America
Morgan Chemicals, Inc.
New Jersey Metals Co.
Niagara Falls Metals & Minerals, Inc.
The Ore & Chemical Corp.
Overseas Metals & Ore Corp.
Parkans International, Inc.
Skandia Metals Corp.
Stainless Processing Co.
Stalco International
Joseph Tyson & Co.
Var-Lac-Oid Chemical Co.
Max Zuckerman & Sons, Inc.

ADDENDA

The information listed below was received too late for inclusion in the foregoing directory:

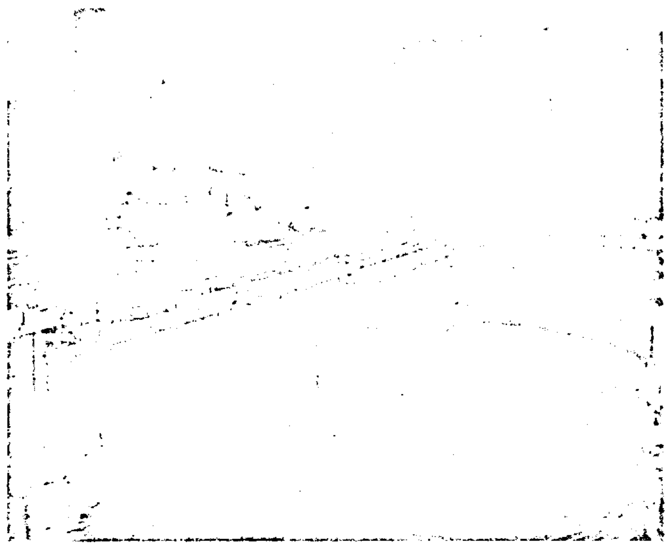
FOOTE MINERAL CO., Route 100, Exton, Pa., 19341, supplies vanadium alloys, ferrovanadium, pentoxide and vanadium chemicals.

MERCER ALLOYS, 2801 Lake Street, Melrose Park, Ill. 60160, supplies vanadium alloys, ferrovanadium, granules, high purity (99.5% plus), pentoxide, powder, and is a buyer of scrap residues.

MERCER ALLOYS, One Alloy Rd., Greenville, Pa. 16126, is a buyer of scrap and residues.

SHIELDALLOY CORP., West Boulevard, Newfield, N.J. 08344, supplies vanadium alloys, ferrovanadium, high purity (99.5% plus,) ingots, billets, powder, and chemical compounds.

WOLVERINE-SITKIN ALLOYS, INC., 6500 E. Robinwood, Detroit, Mi. 48234, supplies vanadium metal, ferrovanadium, and vanadium bearing slag, skims, and residues.



In these giant washing tanks at Union Carbide's plant in Rifle, Colorado, leached sands are separated from the liquors containing the dissolved vanadium and uranium. From here, the liquors go to the solvent extraction operation where vanadium is separated from uranium.

Ore containing vanadium and uranium is roasted in this rotary kiln at Union Carbide's Mining and Metals Division plant in Rifle, Colo.

Buyers' Guide to Suppliers of Vanadium

Suppliers of Vanadium and Vanadium Products:

A

ALLOCHEM INC.
611 Lexington Ave
New York, N.Y. 10022

AMERICAN METAL CLIMAX, INC.
1270 Avenue of the Americas
New York, N.Y. 10020

ASSOCIATED METALS & MINERALS CORP.
733 Third Ave.
New York, N.Y. 10017

ATOMERGIC CHEMETALS CO.
Div. of Gallard-Schlesinger
Chemical Mfg. Corp.
584 Mineola Ave.
Carle Place, L.I., N.Y. 11514

B

BELMONT SMELTING & REFINING
WORKS, INC.
330 Belmont Ave
Brooklyn, N.Y. 11207

S. BORNSTEIN METALS, INC.
1690 Vanderbilt Rd
Birmingham, Ala. 35234

BRAM METALLURGICAL CHEMICAL CO.
245 W. Chelten Ave.
Philadelphia, Pa. 19144

BRANDEIS, GOLDSCHMIDT & CO., INC
610 Fifth Ave.
New York, N.Y. 10019

C

CENTRIFUGAL PRODUCTS, INC.
3245 Cherry Ave.
Long Beach, Calif. 90807

CHICAGO DEVELOPMENT CORP.
5810 47th Ave
Riverdale, Md. 20840

COMETALS, INC
450 W. 33rd St.
New York, N.Y. 10001

CONTINENTAL ORE CORP.
245 Park Ave.
New York, N.Y. 10017

D

DAUB STEEL & METALS CORP
229 Park Ave.
New York, N.Y. 10017

DERBY & CO., INC.
100 Fleet St
Pittsburgh, Pa. 15220

DERBY METALS & MINERALS LTD.
1215 Sherbrooke St., West
Montreal 25, Quebec, Canada

E

EMPIRE STEEL TRADING CO., INC.
80 Wall St.
New York, N.Y. 10005

F

FOOTE MINERAL CO.
Route 100
Exton, Pa. 19341

FRANKEL CO., INC.
19300 Filer Ave.
Detroit, Mich. 48234

H

HALEY SMELTING, INC
6505 Southington Dr.
Parma, Ohio 44129

L.B. HEDGER & SONS METAL CO.
3121 Harvard
Collinsville, Ill. 62234

HIGHVELD STEEL & VANADIUM CORP.,
LTD.
7 Rolls Bldgs., Fetter Lane
London, E.C. 4, England

K

KOLON TRADING CO., INC
55 Broad St.
New York, N.Y. 10004

L

LEGAULT METALS, INC.
312 Second St.
Amos, Quebec, Canada

LEGAULT METAL, INC.
558 Cure Boivin
Sts. Therses, Quebec, Canada

FRED H. LENWAY & CO., INC.
196 California St.
San Francisco, Calif. 94111

M

H.S. MANN MINERALS & METALS CORP.
1549 N. Fishburn Ave.
Los Angeles, Calif. 90063

MATERIALS RESEARCH CORP.
Route 303
Orangeburg, N.Y. 10962

MEFCO, A TELEDYNE CO.
1537 Sterling Ave.
Elkhart, Ind. 46514

MERCER ALLOYS CORP.
1 Alloy Rd.
Greenville, Pa. 16125

THE METAL BANK OF AMERICA
6801 State Rd.
Philadelphia, Pa. 19111

METAL TRADERS, INC.
445 Park Ave.
New York, N.Y. 10022

MORGAN CHEMICALS, INC.
1200 Niagara St.
Buffalo, N.Y. 14213

N

NEW JERSEY METALS CO.
100 Evergreen Pl.
East Orange, N.J. 07018

NIAGARA FALLS METALS & MINERALS
INC.
P.O. Box 225
Buffalo, N.Y. 14217

O

THE ORE & CHEMICAL CORP.
235 E. 42nd St.
New York, N.Y. 10017

OREGON METALLURGICAL CORP.
Box 580
Albany, Ore. 97321

OVERSEAS METAL & ORE CORP.
300 Central Park West
New York, N.Y. 10024

P

PARKANS INTERNATIONAL, INC.
5321 Armour Dr.
Houston, Texas 77020

LLOYD M. PARKANS CO.
2216 Walker Ave.
Houston, Texas 77003

PHILIPP BROTHERS
Div. of Engelhard Minerals
& Chemicals Corp.
299 Park Ave.
New York, N.Y. 10017

POLY RESEARCH CORP.
40 Middle Neck Rd
Great Neck, N.Y. 11021

R

RDG ALLOYS, INC.
Box 53
Robesonia, Pa. 19551

REACTOR EXPERIMENTS, INC.
963 Terminal Way
San Carlos, Calif. 94070

READING ALLOYS, INC.
P.O. Box 53
Robesonia, Pa. 19551

RESEARCH INORGANIC CHEMICAL CORP.
11686 Sheldon St.
Sun Valley, Calif. 91352

ROLLA SITKIN METALS, INC.
718 E. Slauson Ave.
Los Angeles, Calif. 90011

S

SAMINCORP.
South American Minerals &
Merchandise Corp.
445 Park Ave.
New York, N.Y. 10022

SCHIAVONE-BONOMO CORP.
Foot of Jersey Ave.
Jersey City, N.J. 07302

SHIELDALLOY CORP.
N. West Blvd.
Newfield, N.J. 08344

SKANDIA METALS CORP.
663 Fifth Ave.
New York, N.Y. 10022

STAINLESS PROCESSING CO.
11900 S. Cottage Grove Ave.
Chicago, Ill. 60628

STALCO INTERNATIONAL
110 E. 59th St.
New York, N.Y. 10022

STEEL SALES CORP.
2548 S. Pulaski
Chicago, Ill. 60623

STEVENS METALLURGICAL CORP.
342 Madison Ave.
New York, N.Y. 10017

T

C. TENNANT SONS & CO. OF
NEW YORK
100 Park Ave.
New York, N.Y. 10017

TREIBACHER CHEMISCHE WERKE
Aktiengesellschaft
A-9330 Treibach, Austria

JOSEPH TYSON & CO.
514 Ryers Ave.
Cheltenham, Pa. 19012

U

UNION CARBIDE CORP.
Mining & Metals Div.
270 Park Ave.
New York, N.Y. 10017

DEPOTS POTENTIELS DE VANADIUM DANS LE MONDE PRESENTEMENT A L'ETUDE

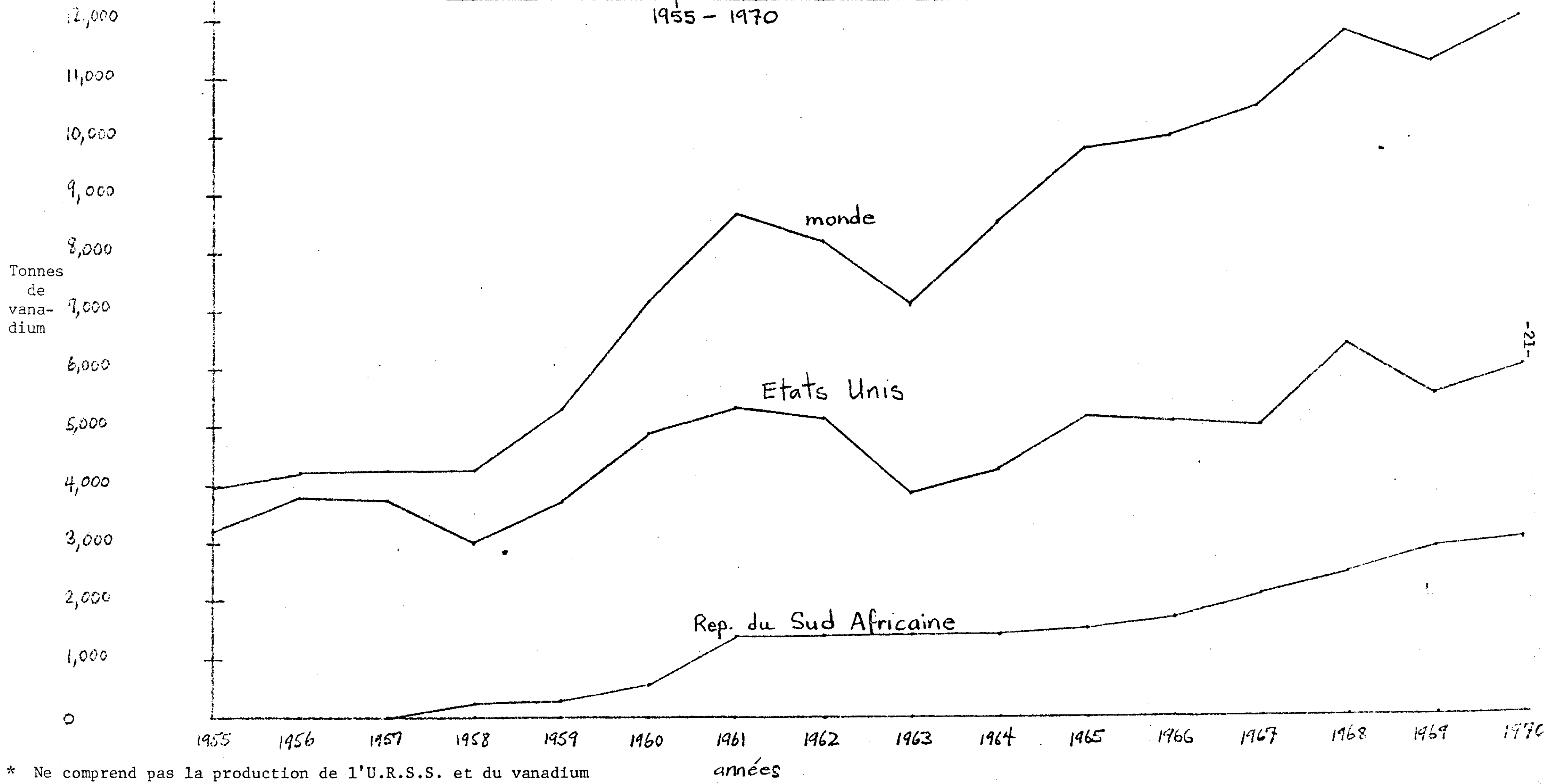
TABLEAU 16

PAYS	LOCALISATION	TYPE DE GISEMENT	RESERVES ET TENEURS	COMMENTAIRES SUR LE PROJET
Inde	district Singbhum de Bihar et district Mayurbanj de Orissa	magnétite titanifère	22 millions de tonnes titrant 1.5 à 2.5% de V_2O_5 10 à 16% de T_1O_2	usine pilote en opération traitant 1 tonne de minerais par jour pour produire du V_2O_5
Mozambique	Tete	magnétite titanifère	minimum 35 millions de tonnes	prévoit récupérer le vanadium et le titane comme sous-produit de la production de fer et d'acier
U.R.S.S.	sidérurgie Serof	magnétite titanifère	ND	produira des ferro-vanadium à partir de la scories de vanadium de la magnétite titanifère des monts Ural
Australie	district de Blade Range de la rivière East Murdrison	magnétite titanifère	dépôt de 12 à 14 milles de long et contenant 240 millions de tonnes de minerais pour chaque 100 pieds de profondeur	exploré présentement par Ferovanaduim Corporation; prévoit produire l'équivalent de 9 millions de livres par an de vanadium sous forme de V_2O_5 projet à l'étude
Australie	prospect Julia Creek (Queensland)	shiste bitumineux	ND	prévoit produire 20 millions de livres de V_2O_5 par an; le vanadium serait récupéré comme co-produit du pétrole. Problème: impact d'une telle offre sur le marché mondiale; enquête de marché en Europe et non au Japon
Canada	Canton Rinfret Province de Québec	magnétite titanifère	72 millions de tonnes titrant 31% Fe, 0.50% V_2O_5	étude préliminaire démontre qu'après une première concentration, on obtien un concentré titrant 62.68% Fe, 1.14% V_2O_5 et 8.81% T_1O_2

ND: Non disponible
Sources: revues de presse

Graphique II.

Evolution de la production mondiale de vanadium*
1955 – 1970



* Ne comprend pas la production de l'U.R.S.S. et du vanadium contenu dans les scories sud-africaines.

Tableau 11

PRODUCTION MONDIALE DE VANADIUM EN
MINERAIS, CONCENTRES ET OXYDES
1955-1970
(tonnes courtes de vanadium)

PAYS	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970[e]
Etats-Unis	3,286	3,867	3,691	3,030	3,719	4,971	5,343	5,211	3,853	4,362	5,226	5,166	4,963	6,483	5,577	6,000
Rep. de l'Afrique du Sud[1]			8	316	320	656	1,422	1,393	1,391	1,282	1,519	1,711	2,115	2,498	2,873	3,000
Sud-Ouest Africain	632	308	305	435	719	838	1,145	1,019	1,134	1,111	1,275	1,353	1,323	560	450	700
Finlande		43	290	430	556	625	701	629	771	1,084	1,063	1,069	1,292	1,321	1,484	1,400
Norvège										670	750	730	816	937	965	900
Rhodésie du Nord						146	107									
Autres pays	78				7		4	12	6	1	1					
TOTAL	3,996	4,229	4,295	4,235	5,321	7,236	8,722	8,264	7,155	8,510	9,834	10,029	10,509	11,799	11,349	12,000

e: estimation
1: vanadium contenu dans l'anhydride vanadique; ne comprend pas le vanadium obtenu du traitement de scories, dont la production par Highveld Steel & Vanadium Corp. a débuté en 1968 (capacité de production: 6,200 t.c./an)
Source: Canadian Minerals Yearbooks, Ottawa
Minerals Yearbook, US Bureau of Mines

Tableau 12

PRODUCTEURS MINIERS DE VANADIUM EN MINERAIS, CONCENTRES ET OXYDE
ETATS-UNIS - 1970

Sociétés	Localisation du gisement	Type de gisement	Type de produit	Capacité annuelle de production	Réserves (en vanadium ou minerai)	Teneur du minerai
Union Carbide Corp.[1] (Mining & Metals Division)	Wilson Spring, Art.	Vanadifère	Oxyde de vanadium (produit primaire)	5,000 t.c. de V_2O_5	30,000 t.c. de V	0.56% de V
	La Sal, Utah	Vanadium-uranium	Oxyde de vanadium (sous-produit)	ND	40,000 t.c. de V (possible)	1.25 à 2.0% de V_2O_5
	Rifle, Colorado	Vanadium-uranium	Oxyde de vanadium (sous-produit)	ND		
Kerr-McGee Chemical Corp.	Soda Spring, Ida.	Calcaire phosphotique	Oxyde de vanadium (sous-produit)	ND	ND	0.2 à 0.3% de V
Susquehanna Corp.[1]	Edgemont, S.D.	Vanadium-uranium	Oxyde de vanadium (sous-produit)	ND	ND	ND

ND: non disponible
1: produisent aussi du ferro-vanadium
t.c.: tonnes courtes

Tableau 13

PRODUCTEURS MINIERS MONDIAUX* DE VANADIUM EN MINERAIS, CONCENTRES ET OXYDE - 1970

Sociétés	Localisation du gisement	Type de gisement	Type de produit	Capacité annuelle de production	Réserves et teneur du minerai
			REPUBLIQUE D'AFRIQUE DU SUD		
Highveld Steel & Vanadium[1] Corporation	Transvaal	Magnetite-titanifère	Scories de vanadium (co-produit)	12,000 t.c. de V_2O_5	200 millions de tonne titran 55 à 57% Fe, 12 à 15% TiO_2, 1.4 à 1.9% V_2O_5
Vantra Division of Highveld	Transvaal	Magnetite-titanifère	Oxyde de vanadium (produit primaire)	3,250 t.c. de V_2O_5	
Ucar Minerals (UCC)[1]	Transvaal	Magnetite-titanifère	Oxyde de vanadium (produit primaire)	1,500 t.c. de V_2O_5	ND
			FINLANDE		
Rautaruukki Co.	Mine Otanmäki	Magnétite-titanifère	Oxyde de vanadium (sous-produit)	3,000 t.c. de V_2O_5	50 millions de tonne titrant 35% Fe, 12 à 15% TiO_2, 0.3%V
			SUD-OUEST AFRICAIN		
South-West Africa Co. Ltd	Mine Berg Aukas	Plomb-zinc	Concentré de Pb-V (sous-produit)	+5,000 t.c. de concentré de Pb-V titrant 17% de V_2O_5	18 millions de tonne titrant 5% Pb, 24% Zn et 0.7% V_2O_5
			NORVEGE		
Christiania Spigerverk[1] Co. (Bremanger Smelterverk Div.)	Mine Rodsand	Magnetite-titanifère	Concentré de magnétite-vanadifère	200,000 t.c. de concentré de magnétite-vanadifère titrant 63% et 0.5% V	ND

ND: non disponible
1: produisent aussi du ferro-vanadium
*: exception faite des Etats-Unis
t.c.: tonne courte