39/85

IN THE PRIVY COUNCIL

NO. 28 of 1985

ON APPEAL
FROM THE COURT OF THE SUPREME COURT OF WESTERN AUSTRALIA

BETWEEN:

HAMERSLEY IRON PTY LIMITED

Appellant
(Respondent)
(Plaintiff)

- and -

1. THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED,
2. LANGLEY GEORGE HANCOCK,
3. ERNEST ARCHIBALD MAYNARD WRIGHT,
4. HANCOCK PROSPECTING PTY LTD,
5. WRIGHT PROSPECTING PTY LTD AND
6. L.S.P. PTY LTD

Respondents
(Appellants)
(Defendants)

RECORD OF PROCEEDINGS

PART II
VOLUME II

Ince & Co.
Knollys House
11 Byward Street
LONDON, EC3R 5EN

SOLICITORS FOR THE APPELLANT
(RESPONDENT) (PLAINTIFF)

WALTONS & MORSE
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31-35 FENCHURCH STREET
LONDON, EC3M 3NN

SOLICITORS FOR THE RESPONDENTS
(APPELLANTS) (DEFENDANTS)

IN THE PRIVY COUNCIL NO.

ON APPEAL

FROM THE FULL COURT OF THE SUPREME COURT OF WESTERN AUSTRALIA

BETWEEN:

HAMERSLEY IRON PTY LIMITED	Appellant (Respondent) (Plaintiff)
- and -	
LANGLEY GEORGE HANCOCK, ERNEST ARCHIBALD MAYNARD WRIGHT, HANCOCK PROSPECTING PTY LTD, WRIGHT PROSPECTING PTY LTD AND L.S.P. PTY LTD AND THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED	Respondents (Appellants) (Defendants)

RECORD OF PROCEEDINGS
INDEX OF REFERENCE

PART II
VOLUME II

IN THE PRIVY COUNCIL NO.

ON APPEAL

FROM THE FULL COURT OF THE SUPREME COURT OF WESTERN AUSTRALIA

BETWEEN:

HAMERSLEY IRON PTY LIMITED
Appellant
(Respondent)
(Plaintiff)

- and -

LANGLEY GEORGE HANCOCK, ERNEST
ARCHIBALD MAYNARD WRIGHT, HANCOCK
PROSPECTING PTY LTD, WRIGHT
PROSPECTING PTY LTD AND L.S.P. PTY LTD AND
THE NATIONAL MUTUAL LIFE
ASSOCIATION OF AUSTRALASIA LIMITED
Respondents
(Appellants)
(Defendants)

RECORD OF PROCEEDINGS
INDEX OF REFERENCE

3. Defendants' Evidence

IN THE FULL COURT OF THE SUPREME COURT

PART II

EXHIBITS

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	Exhibit "7"	1976-77 Pit and Quarry Handbook and Buyer's Guide, 69th Edition, pages B170 to 177 only	1976-77	1329 - 1336
	Exhibit "8"	Affidavit of Douglas Frederick Tompsitt	24th May 1983	1337 - 1338
	Exhibit "8 DFT1"	26 photographs of feed at various stages of processing in the Tom Price concentrator	23rd March 1983	1339 - 1352
	Exhibit "9"	Affidavit of Alban Jude Lynch	22nd May 1983	1353 - 1358
	Exhibit "9 AJL1"	Copy Appendix 'A' to Mineral Processing" by E.J. Pryor, 3rd Ed. - Glossary of Terms	1965	1359 - 1369
	Exhibit "9 AJL2"	Copy extract from "Principles of Mineral Dressing" by A.M. Gaudin		1370 - 1377
	Exhibit "10"	"Handbook of Mineral Dressing" by Taggart, pages 2-134 to 2-140 inclusive	1976	1378 - 1384
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	Exhibit "12"	Affidavit of Arthur Noel Pritchard	24th May 1983	1406 - 1415
	Exhibit "13"	Two brochures by Dorr-Oliver and by Hayl & Patterson		1416 - 1423
	Exhibit "14"	Terms and Definitions of the Vibrating Screen Manufacturers Association	1967	1424 - 1441
	Exhibit "15(1)"	Affidavit of Robin John Batterham	25th May 1983	1442 - 1446
	Exhibit "15(2)"	Amended paragraph 5 to the Affidavit of Robin John Batterham	25th May 1983	1447

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Exhibit "16(2)"	Diagram showing simulation of scrubbing and screening of Tom Price Concentrator		1449
Exhibit "16(3)"	Diagram showing simulation of scrubbing and screening of Tom Price Concentrator		1450
Exhibit "17"	Copy Chapter 9 from "Mineral Processing" by Pryor	1965	1451 - 1504
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Exhibit "19"	Affidavit of Desmond Evered Wright	30th May 1983	1532 - 1534
Exhibit "20"	Brochure by Mt Newman Mining Company entitled "Beneficiation Plant"	1979	1535 - 1546
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Exhibit "23ECH2"	Extract from Bulletin of the University of Minnesota - Mining Directory 1963 Issue	1963	1610 - 1612
Exhibit "23ECH3"	Extract from "Economic Aspects of Iron Ore Preparation" prepared by the Secretariat of the Economic Commission for Europe, 1966	1966	1613 - 1630

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Exhibit "26"	South Australian Broken Hill Proprietary Company Steel Works Indenture Act, 1958	1958	1638 - 1663
Exhibit "27"	Two pamphlets entitled "Iron Ore" published by the Geological Survey of Western Australia, 1966 (copy) and 1983	1966, 1983	1664 - 1705
Exhibit "28"	Copy pages 7-01, 7-06, 7-36 and 7-37 of Taggart's "Handbook of Mineral Dressing"	1976	1706 - 1709
Exhibit "29"	Affidavit of Niles Earl Grosvenor	27th October 1982	1710 - 1719
Exhibit "29NEG1"	Copy letter from Plaintiff's Solicitor to C.R. Fieldhouse	21st October 1982	1720
Exhibit "29NEG2"	Drawing P-004-5041 General Arrangement Section B, of Tom Price Concentrator Washing and Screening Plant	7th December 1976	1721
Exhibit "29NEG3"	Drawing P-004-5033 General Arrangement of Tom Price Concentrator Washing and Screening Plant Wet Feeder	18th May 1977	1722
Exhibit "29NEG4"	Copy booklet "Vibrating Screen - Theory and Selection" published by Allis-Chalmers		1723 - 1748
Exhibit "30"	Copies pages 108, 115, 119-120, 127-132 and 149 of a compilation of extracts from the American Engineering and Mining Journal	1930's - 1950's	1749 - 1760
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	Exhibit "32"	Hamersley Iron "Resources Technology Operations" Booklet, page 16, Plant Layout, Mt Tom Price	January 1981	1762
	Exhibit "33"	Affidavit of Peter Forbes Booth (with exception of paragraph 4)	27th October 1982	1763 - 1770
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	Exhibit "34PFB1"	Copy Conceptual Drawings of Wet Feeder Designs		1774 - 1775
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	Exhibit "35"	Affidavit of Geoffrey Samuel Baker	17th October 1983	1777 - 1779
	Exhibit "36"	Affidavit of Christian Frederick Beukema	22nd June 1983	1780 - 1789
	Exhibit "36CFB1"	Copy United Nations Survey of World Iron Ore Resources, 1955	1955	1790 - 1798
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	Exhibit "39"	Affidavit of Neville Oliver Boughton (excluding paragraphs 6, 7 & 8, the last sentence of paragraph 9 and paragraphs 12 to 15 inclusive)	20th October 1983	1813 - 1820
	Exhibit "39NOB1"	Copy article entitled "Iron ore Concentration Plant of Hamersley Iron Pty Ltd, Mt Tom Price W.A." by Colin R. Langridge.		1821 - 1823

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Exhibit "39NOB2"	Copy article entitled "Developments in Iron Ore Mining and Treatment in Australia, 1960-1978" by R.T. Madigan		1824 - 1826
Exhibit "39NOB3"	Copy letter Plaintiff to Hancock & Wright and attached statements	14th June 1979	1827 - 1831
Exhibit "39NOB4"	Copy letter Plaintiff to Hancock & Wright and attached statements	5th May 1981	1832 - 1837
Exhibit "39NOB9"	Copy letter Plaintiff's Solicitor to Messrs Keall Brinsden & Co.	30th August 1983	1838
Exhibit "39NOB10"	Copy letter Keall Brinsden & Co to Plaintiff's Solicitor	16th September 1983	1839 - 1840
Exhibit "39NOB11"	Letter Plaintiff's Solicitor to Keall Brinsden & Co	23rd September 1983	1841
Exhibit "39NOB12"	Copy letter Keall Brinsden & Co to Plaintiff's Solicitor	6th October 1983	1842 - 1843
Exhibit "40"	Photograph of Tom Price Concentrator Mimic Panel, with enlargement	1983	1844
Exhibit "41A"	Photograph of material on small screens	1983	1845
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Exhibit "42"	Two photographs of material coming from primary wet screens	1983	1847
Exhibit "43"	Flow Chart of Concentrator Medium Drum Plant	30th July 1976	1848
Exhibit "44"	Chart of Isometric Arrangement of Tom Price Concentrator Plant	23rd June 1977	1849
Exhibit "45"	Affidavit of Ernest Archibald Maynard Wright	20th October 1983	1850 - 1852

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Exhibit "45EAW1"	Copy backing Sheet of Agreement		1853
Exhibit "45EAW2"	Bundle of correspondence	Various	1854 - 1911
Exhibit "45EAW3"	Bundle of draft Agreements	Various	1912 - 1975
Exhibit "45EAW4"	Copy letter Second Defendant to John Hohnen	12th June 1962	1976 - 1977
Exhibit "46"	Affidavit of Ernest Archibald Maynard Wright	24th October 1983	1978
Exhibit "46EAW5"	Copy letter F.S. Anderson to Second Defendant	15th November 1962	1979 - 1982
Exhibit "47"	Copy pages 46 to 48 inclusive of "Mining Magazine" Jan. 1978 Edition	January 1978	1983 - 1985

DOCUMENTS NOT TRANSMITTED TO THE PRIVY COUNCIL

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Summons for Directions and order thereon	22nd April 1983 2nd June 1983	
Affidavit of Nicholas Paul Hasluck	30th May 1983	
Exhibits "8DFT2-11" to the affidavit of Douglas Frederick Tompsitt sworn 24th May 1983 were not documents but were samples of iron ore feed		
Exhibits "NOB5-8" to the Affidavit of Neville Oliver Boughton sworn 20th October 1983		
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Notice of Motion in Appeal No 60 of 1984 for leave to Appeal to the Full Court	13th February 1984	

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Order in Appeal No 59 of 1984 (inter alia) for Appeals to be heard together and for one set of Appeal Books	20th March 1984	
Order in Appeal No 60 of 1984 (inter alia) for Appeals to be heard together and for one set of Appeal Books	20th March 1984	
Certificate of Correctness of Transcript of Hearing before the Honourable Mr Justice Olney	4th May 1984	
Notice of Motion in Appeal No 59 of 1984 for leave to Appeal to Her Majesty in Council	20th December 1984	
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Affidavit of Colin Roy Langridge in Appeal No 60 of 1984	20th December 1984	
Affidavit of Malcolm Roger Joseph Randall in Appeal No 59 of 1984	20th December 1984	
Affidavit of Malcolm Roger Joseph Randall in Appeal No 60 of 1984	20th December 1984	

XHIBIT "11"-Australian Standard
418, Part 1 - 1980, Terms Relating
o Coal Preparation 1980

AS 2418, Part 1—1980
UDC 662.62:001.4

Australian Standard
2418, Part 1—1980

GLOSSARY OF TERMS RELATING TO SOLID MINERAL FUELS

Part 1—TERMS RELATING TO COAL PREPARATION

STANDARDS ASSOCIATION OF AUSTRALIA
Incorporated by Royal Charter

EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
to Coal Preparation 1980

May 1982

STANDARDS ASSOCIATION OF AUSTRALIA
Incorporated by Royal Charter

CORRIGENDA
to
AS 2418, Part 1—1980
GLOSSARY OF TERMS RELATING TO SOLID MINERAL FUELS
PART 1—TERMS RELATING TO COAL PREPARATION

Published on 17 May 1982.

Page 3. **actual performance curve**—*alter* 'that' to 'the'

Page 6. **disintegration**—*insert* 'by' after 'in water or'

Page 7. **equipment flowsheet**—*add* '(a)' after '*See* flowsheet'

Page 9. **jigging screen**—*add* '(d)' after '*See* screen'
Page 9. **liquids flowsheet**—*add* '(b)' after '*See* flowsheet'

Page 10. **materials flowsheet**—*add* '(c)' after '*See* flowsheet'
Page 10. **nominal area** (of a screen)—*add* '(*See* effective area of a screen) after 'feed'

Page 11. **open circuit**—*alter* 'product' to 'products'
Page 11. **open loop control**—*add* '(a)' to '*See* loop control'
Page 11. **percentage open area**—*add* '(*See* effective screening area)' after 'cloth'

Page 12. **primary cells**—*add* '(a)' after '*See* cells'
Page 12. **reject elevator**—*alter* 'washing' to 'cleaning'

Page 13. **rougher cells**—*add* '(a)' after '*See* cells'
Page 13. **scavenger cells**—*add* '(c)' after '*See* cells'

Page 15. **total of misplaced material** (line 3)—*alter* 'mass' to 'masses'

EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
to Coal Preparation 1980

Hancock and Wright, Perth

THE FOLLOWING INDUSTRIAL, SCIENTIFIC AND GOVERNMENTAL ORGANIZATIONS and departments were officially represented on the committee entrusted with the preparation of this standard:

Australian Coal Association
Australian Institute of Energy
Australasian Institute of Mining and Metallurgy
Bureau of Steel Manufacturers of Australia
Coal Preparation Societies of N.S.W. and Queensland
Confederation of Australian Industry
Department of Minerals and Energy, Victoria
Department of Mineral Resources, N.S.W.
Department of National Development
Electricity Supply Association of Australia
Institution of Engineers, Australia
Joint Coal Board
Queensland Coal Board
Royal Australian Chemical Institute
Universities

This standard, prepared under the direction of Committee MN/1, Coal and Coke, was approved by the Council of the Standards Association of Australia on 10 October 1980, and was published on 1 December 1980.

To keep abreast of progress in industry, Australian standards are subject to continuous review and are kept up-to-date by the issue of amendments or new editions as necessary. It is important therefore that standards users ensure that their standards are up-to-date. Full details of all SAA publications will be found in the Annual List of Australian Standards; these details are supplemented by listings in the SAA monthly journal 'The Australian Standard'. Information on the Annual List and 'The Australian Standard' may be obtained from any sales office of the Association, where details are also available of the current status of individual standards. Suggestions for improvements to published standards, addressed to the head office of the Association, are welcomed.

This standard was issued in draft form for public review as DR 79159.

EXHIBIT "11"-Australian Standard 2418, Part 1 - 1980, Terms Relating to Coal Preparation 1980

AUSTRALIAN STANDARD

GLOSSARY OF TERMS RELATING TO SOLID MINERAL FUELS

Part 1

TERMS RELATING TO COAL PREPARATION

AS 2418, Part 1—1980

First published (as AS K181) 1968
AS 2418, Part 1 first published 1980

PUBLISHED BY THE STANDARDS ASSOCIATION OF AUSTRALIA
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EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
to Coal Preparation 1980

PREFACE

This standard was prepared by the Association's Committee on Coal and Coke under the direction of the Minerals Standards Committee as a revision of AS K181—1968 which it accordingly supersedes. It contains terms which are currently in use in coal preparation in Australia and internationally.

This standard is based on AS K181—Glossary of Terms Used in Coal Preparation, and the draft revision of ISO 1213/Part 1—Vocabulary of Terms Relating to Solid Mineral Fuels, Part 1—Terms Relating to Coal Preparation.

EXHIBIT "11"-Australian Standard 2418, Part 1 - 1980, Terms Relating to Coal Preparation 1980

STANDARDS ASSOCIATION OF AUSTRALIA

Australian Standard
GLOSSARY OF TERMS RELATING TO SOLID MINERAL FUELS

PART 1—TERMS RELATING TO COAL PREPARATION

Term	Explanation
activator activating agent	A substance which when added to a pulp promotes flotation in the presence of a collecting agent.
actual performance curve	A performance curve showing that results actually obtained from a coal preparation treatment (*see also* performance curve).
actuator	The final item in a control system which adjusts the setting of the controlled variable in accordance with instructions received from the controller.
aeration	The introduction of air into the pulp in a flotation cell in order to form air bubbles
agglomeration	A process in which small particles are caused to adhere to one another.
agitator	A device used to bring about a continuous vigorous disturbance in a pulp, frequently used to assist bubble formation.
air classification	The process of particle sizing in a current of air (*see also* classification).
air compressor	A compressor, either rotary or reciprocating, used to produce air at a pressure suitable for specific operations in the coal preparation plant.
air jig	A machine in which the feed is stratified according to its relative density by means of pulsating currents of air and from which the stratified products are separately removed.
air valve (jig)	The valve which controls the alternate admission and release of compressed air to each cell of a jig.
amplitude	The maximum displacement from the mean position in an oscillating motion. In the case of a screen with a straight line motion or elliptical motion, it is half of the total movement or half of the major axis of the ellipse. In the case of a circular motion, it is the radius of the circle (*see also* stroke).
angle of reclaim	The maximum angle between the surface of the material and the horizontal plane formed as the material is being reclaimed. It is dependent on the conditions existing at the time of measurement.
angle of repose	The maximum angle contained between the surface of a heap of loosely piled material and the horizontal.
aperture (size)	The dimension or dimensions defining the opening in the screening surface, usually with a qualification as to the shape of aperture, e.g. 'round-hole', 'square-mesh' 'long-slot', 'wedge-wire'.
apron feeder	*See* feeder (a).
ash error	The difference between the actual percentage ash of a product of a separation and that shown by the washability curve (based on the reconstituted feed) corresponding to the actual yield obtained.
ash, inherent	Ash derived from mineral matter intimately associated with coal and not readily separable by physical processes.
ash monitor	A device which, either continuously or intermittently, indicates the percentage of ash in the feed or product of a coal preparation operation.
ash—relative density curve	The curve obtained from the float and sink analysis by plotting the percentages of ash in successive fractions against the mean relative density of the fraction.
ash, total	The inorganic residue after the incineration of coal or coke to constant mass under standard conditions. In general, it differs in mass and composition from the original mineral matter.
baffle	A device such as a steel plate, used to check, retard or divert the flow of materials
bag filter	An apparatus for removing dust from dust-laden air, employing containers of closely woven material which permit passage of air but retain solid particles.
ball mill	A container, generally cylindrical, rotating on a horizontal axis and partly filled with balls (e.g. of steel) which, by their tumbling motion, reduce the feed into a finely comminuted material.
balling	*See* nodulizing *and* agglomeration.
bar screen	*See* screen (a).
barometric leg	The pipe connection between the moisture trap and water seal in the vacuum arrangement of a filter installation.

SUPREME COURT WESTERN AUSTRALIA

EXHIBIT "11"-Australian Standard 2418, Part 1 - 1980, Terms Relating to Coal Preparation 1980

barrel washer	A washer comprising a cylinder rotating slowly about an axis which is slightly inclined to the horizontal and into which the raw coal, with a current of water or of a suspension, is fed near its upper end. The clean coal is carried by the water or suspension to the lower end of the cylinder over a scroll which conveys the reject to the upper end of the cylinder.
basket centrifuge	*See* centrifuge, basket.
bath	A vessel containing a medium used to separate coal by the float and sink method.
Baum jig	A jig in which the pulsating motion of the water is produced by the intermittent admission of compressed air (*see also* air jig).
belt feeder	*See* feeder (b).
belt weigher	Apparatus used to quantify the mass flow of a material on a belt conveyor.
beneficiate	To increase the commercial value of a coal by appropriate treatment.
bin	A vessel used for the storage of materials, the lowermost portion of which is usually constructed in the form of a hopper.
bleed	Portion of total flow removed from a circuit either to balance the circuit or to treat that portion elsewhere.
blending	Mixing in predetermined and controlled quantities to give a uniform feed or product.
blower	*See* air compressor.
boom loader	*See* loading boom.
bowl centrifuge	*See* centrifuge, solid bowl *and* centrifuge, screen bowl.
breakage	(a) Voluntary or involuntary size reduction of a solid. (b) Small material produced by involuntary breakage during mechanical handling or processing.
breaking	Reduction in the maximum top size of large particles (e.g. as in run-of-mine coal).
briquetting	The moulding of small or fine coal (with or without the admixture of a binder) into a uniform product of predetermined size and shape by the application of pressure.
bucket wheel loader	*See* loader, bucket wheel.
bulk density	The ratio of the mass of a collection of discrete particles to the volume which it occupies.
cells, flotation	Coal preparation equipment in which froth flotation operations are carried out. They may be the following: (a) *Primary cells (rougher cells)*—a group of flotation cells in which the raw feed is given a preliminary treatment, either or both of the products being subsequently re-treated. (b) *Cleaner (recleaner) cells*—secondary cells for the retreatment of the concentrate from primary cells. (c) *Scavenger cells*—secondary cells for the retreatment of tailings.
centrate	The liquid in a slurry which is separated from the solid material by use of a centrifuge.
centrifuge, basket	A device for de-watering in which wet coal is held by centrifugal force against a surface which permits the outward passage of water and retains the coal, which is discharged mechanically.
centrifuge, solid bowl	A device for de-watering in which the retaining surface is solid. The retained particles are collected by a scroll and discharged from one end of the machine. The water overflows from the opposite end.
centrifuge, screen bowl	A de-watering device combining in one machine a bowl and a basket centrifuge.
centrifuging	De-watering with the aid of centrifugal force.
characteristic ash curve	The curve obtained from the results of a float and sink analysis showing, for any yield of floats (or sinks), the percentage of ash of the highest density (or lowest density) fraction reporting to these floats (or sinks), the yield being plotted on the ordinate (vertical axis) and the percentage of ash on the abscissa (horizontal axis).
check screen	*See* screen (h).
chute	An inclined trough used for the transportation of materials by gravity.
circulating medium	Medium in circulation in a dense medium process.
circulating water	The water in the water circuit (*see* water circuit).
clarification	The concentration and removal of solids from water in order to reduce the suspended solids to a minimum.
clarifier	*See* rake thickener.
classification	The separation of particles according to their particle size, and/or density and/or shape (*see also* screening).
classifier	A device which separates particles, according to their particle size, and/or shape and/or density.
classifying cyclone	*See* cyclone (c).
clean coal cleaned coal	The coal product from a cleaning process (wet or dry).

EXHIBIT "11"-Australian Standard 2418, Part 1 - 1980, Terms Relating to Coal Preparation 1980

cleaning	(a) *Dry*—the separation of impurities from coal by methods not requiring the use of liquids or suspensions. (b) *Wet*—the separation of impurities from coal by methods involving the use of liquids or suspensions.
closed circuit	(a) A water circuit designed so that the only water added is that necessary to replace the loss in the products and that due to atmospheric evaporation. (b) A system of crushing or grinding in which oversize material is separated and recycled.
closed loop control	*See* loop control.
coal cleaning	The treatment of coal to produce a product having a lower mineral matter content.
coal preparation	Collectively, physical, mechanical and/or chemical processes applied to coal to make it suitable for a particular use.
coal preparation plant	A plant in which a coal preparation process is carried out.
collector collecting agent	A reagent added to a pulp to promote adherence between coal particles and air bubbles.
comminution	The processes of particle size reduction.
concentrate, clean coal	The cleaned product from a beneficiation process, e.g. froth flotation.
concentrating table	A device consisting of an inclined riffled deck, to which a differential reciprocating motion is imparted in a substantially horizontal direction; the material to be separated is fed in a stream of water, the heavy particles collect between the riffles and are then conveyed in the direction of the reciprocating motion while the lighter particles are borne by the current of water over the riffles to be discharged laterally from the table.
conditioner	An apparatus in which conditioning takes place.
conditioning	The preparatory stage in the flotation process in which the reagents are brought into intimate contact with the solids of the pulp.
contact angle	The angle between the tangent to the interface and the tangent to the solid surface at any point along the line of contact of the interface between two fluids and a solid; usually measured inside the water phase where water is involved. Maximum and minimum values measured under static conditions, termed 'advancing' and 'receding' contact angles respectively, are usually qualified by stating the phase in which the angle is measured (e.g. oil-advancing contact angle).
control size	A single particle size chosen to test the accuracy of a sizing operation.
control system	An arrangement of measuring devices, controllers and actuators organized and adjusted to control a process in a specified manner.
controller	An instrument usually comprising— (a) a comparator unit for comparing a measured variable and the desired value in a control loop; and (b) the controller itself, which in response to signals from the comparator unit, acts in a direction tending to maintain the desired value.
correctly placed material	Material correctly included in the products of a sizing or density separation, e.g.: (a) *In cleaning*—material of relative density lower than the separation density which has been included in the low density product, or material of relative density higher than the separation density which has been included in the high density product. (b) *In sizing*—undersize contained in the undersize stream or oversize contained in the oversize stream of a sizing operation. (*See also* total of correctly placed material).
crusher	Machinery for the reduction of material into relatively coarse particles.
crushing	Particle size reduction by compressive forces.
cumulative curve	Any curve expressing the results of combining successive relative density fractions or size fractions.
cumulative floats curve	The curve obtained from the results of a float and sink analysis by plotting the cumulative yield of floats at each relative density against the mean percentage of ash of the total floats at that density.
cumulative sinks curve	The curve obtained from the results of a float and sink analysis by plotting the cumulative yield of sinks at each relative density against the mean percentage of ash of the total sinks at that density.
cut-point	*See* separation density, *or* separation size.
cyclone	A vessel consisting of cylindrical and/or conical sections for separating particles, suspended in liquid or gas, by means of centrifugal force imparted by tangential injection of feed. There are five types of cyclones, as follows: (a) *Hydrocyclone*—a cyclone for separating materials suspended in water. (b) *Dense medium cyclone (heavy medium cyclone)*—a cyclone for separating materials, suspended in a dense medium, whereby the particles of higher relative density collect at, and are discharged from, the apex of the vessel, while those of lower relative density are eliminated with the bulk of the dense medium at the overflow orifice.

EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
to Coal Preparation 1980

	(c) *Classifying cyclone (cyclone classifier, desliming cyclone)*—a hydrocyclone for the treatment of fines whereby the coarser particles collect at, and are discharged from, the apex of the vessel, while the finer particles are eliminated with the bulk of the water at the overflow orifice. (d) *Thickening cyclone (dewatering cyclone)*—a classifying cyclone adjusted so that a thickened suspension of the feed solids is discharged at the apex while the bulk of the water is eliminated at the overflow orifice. (e) *Water washing cyclone (water only cyclone)*—a hydrocyclone whereby the particles of higher relative density collect at, and are discharged from, the apex of the vessel, while those of lower relative density are eliminated with the bulk of the water at the overflow orifice.
de-dusting	Fines removal by dry methods.
deep cone thickener	A thickener with an acutely angled conical base designed to discharge an underflow of high pulp density (*see also* rake thickener).
degradation	Involuntary breakage incidental to handling, cleaning and storage.
demagnetize	To promote dispersion, by means of a suitable magnetic field, of solids in a dense medium which have been flocculated magnetically.
dense liquid	A homogeneous liquid or solution of density greater than that of water which can be used in industry or in the laboratory to divide coal into two fractions of different relative densities.
dense medium	A fluid formed by the artificial suspension in water of fine particles of high relative density (e.g. magnetite, barytes, shale), which can be used in industry or in the laboratory to divide coal into fractions of different relative densities.
dense medium cyclone	*See* cyclone (b).
dense medium process	A process for the cleaning of coal, in which the desired separation is effected in a dense medium.
dense medium recovery	The collection, for re-use, of medium solids from dilute medium, usually understood to include the removal, in whole or in part, of contaminating fine coal and clay.
dense medium separator	A device for the cleaning of coal, in which the desired separation is effected using a dense medium process. The separation may be effected by gravity or by the use of centrifugal force.
density control device	An automatic device to control the density of the medium in or entering the dense medium separator.
depressant	In froth flotation, a substance which when added to a pulp prevents a particular component from floating.
design capacity	*See* operational capacities.
designated size	The particle size at which it is desired to separate a feed by a sizing operation.
desliming	The removal of slimes from coal or a mixture of coal and water, however accomplished.
desliming cyclone	*See* cyclone (c).
desliming screen	*See* screen (b).
de-watering	The removal of water from wet materials by means other than evaporation.
dewatering cyclone	*See* cyclone (d).
diaphragm type jig	A jig in which the pulsating motion is produced by the reciprocating movement of a diaphragm.
dilute medium	Medium of density below that in the dense medium separator, usually occurring as a result of spraying the products for the removal of adhering medium solids.
disc filter	A vacuum type filter in which the filtering medium is supported on discs caused to rotate in a vertical plane through the pulp to be de-watered.
discard	The material extracted from the raw coal and finally discarded (*see also* reject).
disintegration	The physical breakdown of material, usually shale, as a result of immersion in water or weathering.
dispersion	(a) A suspension of discrete particles in a fluid. (b) The creation of a suspension of discrete particles in a fluid.
distribution coefficient	*See* partition coefficient.
distribution curve	*See* partition curve.
distributor	A chamber to receive and distribute pulp in any desired proportions through a number of outlets.
drag tank	A tank, forming part of the water circuit, in which slurry or small coal settles and is removed continuously by means of a scraper chain or scraper buckets.
draining	The removal of water or other medium from a product, mainly by gravity.
dressing water	Secondary water used on concentrating tables.

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drum filter	A vacuum type filter in which the filtering medium is supported on drums caused to rotate on a horizontal axis through the pulp to be de-watered.
dry cleaning	*See* cleaning.
dry cleaning table	An apparatus in which dry cleaning is achieved by the application of air currents and agitation to a layer of feed of controlled depth on the table surface.
drying	The removal of moisture, mainly by evaporation.
dry screening	*See* screening.
dust collector	An apparatus for separating solid particles from air or gas and accumulating them in a form convenient for handling.
dust extraction	The removal of solid particles suspended in gas or ambient air.
dust proofing	Containment and sealing of equipment or free space such that dust may neither enter nor escape.
dust suppression	The prevention or reduction of the dispersion of dust into the air, e.g. by water sprays or surface treatment chemicals.
ecart probable moyen (Epm)	*See* probable error.
effective area of a screen	The total area of the screen deck exposed to the flow of the material feed, less any area occupied by fixings or supports which obstruct the passage of material over or through the screen deck.
effective screen aperture	The cut-point (equal errors or partition size) at which the particle sizing operation separates the material tested into two size fractions.
effective screening area	The open area of a screen expressed as a percentage of the nominal area.
efficiency of sizing or screening	The mass of material correctly placed above or below the reference size, expressed as a percentage of the mass of corresponding material in the feed.
effluent	Liquid waste product, which may contain suspended solids.
electrostatic precipitator	An apparatus for removing dust from dust-laden air, employing the principle of electrostatic precipitation.
error area error curve tromp curve	A partition curve drawn to defined conventional scales with the portion showing recoveries over 50 percent reversed to enclose an error area.
equal errors cut-point wolf cut-point	The density at which equal portions of the feed material are wrongly placed in each of two products of a relative density separation.
equal errors size	The separation size at which equal portions of the feed material are wrongly placed in each of two products of a sizing operation.
equipment flowsheet	*See* flowsheet.
false middlings	Comparatively high ash particles consisting of interbanded coal and non-coal material from which the coal may be liberated by crushing.
feed	Material for treatment supplied to an appliance or plant.
feed box head box	A device for distributing a suspension of solids in water to a machine, or for retarding the rate of flow.
feeder	A mechanical device for controlling the rate of supply of feed. It may be one of the following types: (a) *Apron feeder*—a feeder in which the material is carried on a steel plate conveyor and in which the rate of feed is adjusted either by varying the depth of material or the speed of the conveyor, or both. (b) *Belt feeder*—a conveyor for withdrawing solid materials from a hopper or bin and usually supplied with a variable speed drive to enable variable rate discharge. (c) *Reciprocating feeder*—a feeder in which the material is carried on a plate subjected to a reciprocating motion and so constructed that when the plate moves in the reverse direction the material remains stationary. The rate of feed is normally varied by adjusting the stroke of the reciprocating plate. (d) *Screw feeder*—a feeder consisting of a helical-shaped rotating unit either partly or totally enclosed. (e) *Star feeder*—a rotating feeder consisting of a horizontal shaft fitted with radial blades running within a close-fitting cylindrical chamber provided with an inlet and an outlet. (f) *Vibratory feeder*—a feeder consisting of an open-ended tray actuated by a vibration unit, the rate of feed being controlled by varying the amplitude and/or frequency of the vibrations.
feldspar type jig	A jig to clean coal where the pulsating water is made to pass through a layer of graded material, e.g. feldspar, situated on top of the screenplate (*see also* air jig).
filter belt press	A form of pressure filter in which the material being de-watered is supported on a porous belt and pressure is induced to aid water removal from the filter cake.
filter cake	The solids product from a filtration process.
filter cloth	The fabric used as a medium for filtration, e.g. nylon cloth, blanket cloth, finely woven non-corrosive wire mesh, finely woven glass thread (*see also* disc filter, drum filter).

filter press	A form of pressure filter, non-continuous in operation, used in coal preparation for the removal of water from slurries, tailings and similar products.
filter tank	A tank containing the pulp to be filtered, generally fitted with an agitator to maintain the solids in the pulp in suspension and in which the drum or disc of a rotary vacuum filter is partially immersed.
filtrate	The liquid product from a filtration process.
filtration	A process for separating solids from liquids by allowing the liquid to pass through a finely woven cloth or gauze which retains the solids, generally using a pressure differential to accelerate the separation.
fines	Coal with a maximum particle size normally less than 0.5 mm, and with no lower limit. The upper limit may vary widely. To avoid confusion, the term should always be qualified by stating the limiting size.
finger planimeter	A flow rate indicator for determining volumetric rate of flow of a solid-particulate material, in which a series of flexible steel fingers mounted on a common frame is situated above a conveyor belt so that the fingers rest on the belt surface.
fixed screen	*See* screen (c).
float	That part of an automatic refuse extractor which is used to indicate variations in the layer of heavy material on the screenplate.
float and sink analysis	The division of a sample into relative density fractions with defined limits, the proportions of the fractions being expressed as mass percentages of the total sample, commonly with an indication of the ash percentage (and other characteristics, if required) of each fraction.
floats	Fractions with a defined upper limit of relative density defined by the symbol 'F', followed by the numerical value of the upper relative density; e.g. 'F 1.40' describes the floats fraction containing all particles having relative densities less than 1.40.
flocs	Aggregates resulting from flocculation.
flocculant flocculating agent	A polymeric reagent added to a dispersion of solids in a liquid to bring together the fine particles to form flocs.
flocculation	The formation of aggregates from particles dispersed in a liquid by addition of a flocculant.
flood box	(a) *Open*—a water overflow box mounted on screens over which the water falls as a solid curtain across the screen. (b) *Pressurized*—a closed slotted box into which water is pumped giving a curtain spray across the screen.
flotation	*See* froth flotation.
flotation cell	*See* cells.
flotation concentrate	The clean product recovered in froth flotation.
flotation tailings	The reject from froth flotation cells.
flowsheet	A diagram indicating the method of treating the raw coal in a preparation plant by showing in correct sequence the chief units of plant, the principal operations and (normally) the quantities at each stage. The various types of flowsheet are as follows: (a) *Equipment flowsheet*—a flowsheet indicating, preferably with symbols, the units of plant used in the various operational steps carried out within a coal preparation plant. (b) *Liquids flowsheet*—a flowsheet indicating the flow of liquids throughout a series of operations. (c) *Materials flowsheet (capacity flowsheet)*—a flowsheet indicating the quantitative flow of solid materials at designated points in a coal preparation plant. (d) *Process flowsheet*—a flowsheet indicating the main operational steps within a coal preparation plant, the movement of the various materials between the steps and the final products obtained, and often also the average mass flow at various points in the plant. (e) *Weighted flowsheet (capacity flowsheet)*—a materials flowsheet used in the design of a plant, including statements of the maximum mass flow per hour at principal points in the plant. The total mass flow of products from an operation is usually greater than the mass flow of the feed to that operation.
flushing water	Water used to assist the flow of materials in a chute or launder.
freeze-proofing	A surface treatment, as with calcium chloride solution, to prevent or reduce cohesion of coal particles by ice formation during freezing weather.
froth breaker	A device to reduce the volume of froth flotation concentrates by de-aeration.
froth flotation	A process for cleaning fine coal in which the coal particles, with the aid of reagents, become attached to air bubbles in an aqueous medium and are removed in a froth.
froth paddle	A moving blade to remove froth from the lip of a flotation cell.
frother frothing agent	A reagent used to control the size and stability of the air bubbles in the flotation process.
graded coal sized coal	Coal screened between specified particle size limits.

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grindability	A measure of the relative ease of grinding a sample under standard conditions (*see* AS 1038, Part 20).
grinding	Particle size reduction by impact and attrition.
grizzly	A rugged screen for rough sizing at comparatively large size (e.g. 150 mm). It can comprise fixed or moving bars, discs, or shaped tumblers or rollers (*see* screen (a)).
guard screen	*See* screen (h).
hand cleaning hand picking	The removal by hand of impurities from coal.
head box	*See* feed box.
head tank	Any tank or vessel in the fluid circuit which is used to control the delivery pressure of the fluid to the washing units.
heavy medium	*See* dense medium.
heavy medium cyclone	*See* cyclone (b).
homogenization	The thorough mixing of a material to obtain a product of relatively constant characteristics.
hopper	A vessel into which materials are fed, usually constructed in the form of an inverted pyramid or cone terminating in an opening through which the materials are discharged (not primarily intended for storage).
hutch	The part of a jig situated below the screenplate in which the controlled pulsating movement of the water takes place.
hydrocyclone	*See* cyclone (a).
idlers	In a conveyor, rollers for supporting a conveyor belt.
impact box	A container interposed at impact points in the flow of material to resist wear.
imperfection (*I*)	The ratio: $\frac{\text{probable error}}{\text{partition density} - 1}$
inherent ash	*See* ash, inherent.
instantaneous ash curve	*See* characteristic ash curve.
interbanded	Of coal and mineral matter—associated in random horizontal layers, usually with a natural cleavage.
jaw crusher	A machine for reducing the particle size of materials by impact or crushing between a fixed plate and an oscillating plate.
jig	A machine in which the feed is stratified in air or water by means of a pulsating motion and from which the stratified products are separately removed (*see also* air jig, baum jig, feldspar type jig).
jigging	The operation of a jig.
jigging screen	*See* screen.
launder sluice	A trough along which liquids or a mixture of liquids and solids flow.
launder washer	A washer applying the principle of stream classification in troughs.
liberation (of intergrown constituents)	Particle size reduction to free the constituent materials.
liquids flowsheet	*See* flowsheet.
loader, bucket wheel bucket wheel loader	A device consisting of a series of buckets mounted on a large wheel which is revolved in a vertical plane. The buckets successively are caused to dig into stockpiled material at the bottom of the rotating cycle and discharge to a chute and conveyor at the top of the cycle.
loading boom boom loader	A hinged portion of a conveyor which is designed to receive materials at a fixed level and to discharge them at varying levels; usually employed for loading coal into wagons.
loop control	A form of parameter control of which there are two types, viz: (a) *Open loop*—in open loop control a variable parameter is measured and some control action is taken to maintain a final parameter at some fixed or desired value. No measure of the final parameter is taken if variations from the desired value occur. (b) *Closed loop*—in closed loop control the final parameter is measured, and this value is compared with the desired value, and a control signal fed back to adjust one or more input variables.
low grade coal	Coal which has only limited uses owing to undesirable characteristics (e.g. high mineral matter content).
M-curve	*See* Mayer curve.
magnetics	That portion of the dense medium solids which has a high magnetic susceptibility and is therefore readily recovered by magnetic means.
magnetic separator	For medium solids recovery from dilute medium—a device in which medium solids are caused to adhere, by magnetic means, to a conveying belt or drum, while a current of water removes non-magnetic particles which contaminate the medium.

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make-up medium	Medium or medium solids added to the circuit to replace loss during the operation of dense medium cleaning processes.
make-up water	Water supplied to a washery to replace that lost from the circuit.
materials flowsheet	*See* flowsheet.
maximum top size	The minimum size of the aperture (square unless stated otherwise) through which all the material will pass.
Mayer curve M-curve	A cumulative curve used in the first instance to express the washability of coal, plotted on a vectorial diagram in which the projection of the vector on the abscissa (horizontal axis) represents the percentage of the product (coal) and the direction of the vector represents the percentage of a particular constituent of the product.
mean size	The average particle size of any sample, batch or consignment of particulate material. A number of methods for calculating mean particle size have been proposed giving results which vary widely for the same particle size distribution. The method of calculation should always be stated whenever the term is used.
mechanical maximum capacity	*See* operational capacities.
medium	*See* dense medium.
medium draining screen	*See* screen (e).
medium recovery screen	*See* screen (f).
medium solids	The solid component of a suspension in water.
medium solids preparation	Any treatment of the raw dense medium solids to make them suitable for use.
medium solids recovery plant	The equipment used to remove adherent medium solids from a product from a dense medium separator (after drainage of surplus medium), usually by spraying, and to remove contaminating coal and clay from these medium solids.
metering box	A container, in single or multiple portions, with weir or weirs to provide a controlled addition of one or more reagents.
metering pump	A variable, positive displacement pump used to control the addition of reagents to a washery circuit.
middlings	A product of coal preparation which, by reason of its mineral matter content, is intermediate between clean coal and discard.
middlings elevator	An elevator which removes material for further treatment or for disposal as an inferior product.
misplaced material	(a) *In cleaning*—material of relative density lower than the separation density which has been included in the high density product, or material of relative density higher than the separation density which has been included in the low density product. (b) *In sizing*—undersize contained in the oversize stream, or oversize contained in the undersize stream, of a sizing operation.
moisture in air-dried coal	(a) The moisture in the coal sample after it has attained equilibrium with the air to which it is exposed. (b) Moisture retained after air-drying under defined conditions.
moisture, total	(a) The moisture in the coal as sampled, and removable under standardized conditions. (b) Free moisture, plus moisture in air-dried coal, expressed as percentages of the sample as received.
moving sieve jig	A jig in which the screenplate supporting the bed of material under treatment is moved up and down in water.
multi-deck screen	*See* screen (g).
near gravity material	Material with a relative density lying between limits, usually 0.05, on either side of the cut point.
near sized material near mesh material	Material approximating in size to the aperture in the screening surface, usually within ± 25 percent of the aperture of separation.
nodulizing agglomeration	The forming of agglomerates by the application of a gyratory, rotary or oscillatory motion to fine coal, without the use of pressure.
nominal area (of a screen)	The total area of the screen deck exposed to the flow of the material feed.
nominal plant capacity	A nominated figure used in the title of a flowsheet and in the general descriptions of a plant as a whole or for specific unit operations to indicate capacity, usually expressed in tonnes per hour.
nominal screen aperture	A nominated aperture size used to designate the result of a sizing operation.
nominal screening size	A designated size at which it is intended to divide a feed by a screening operation.
nominal size limiting size	The limit or limits of particle size used to describe a product of a sizing operation.
nominal top size	The size of the aperture (square unless stated otherwise) through which at least 95 percent of the material passes.
non-magnetics	That portion of the dense medium solids which has a low magnetic susceptibility. These solids are usually of lower relative density than the magnetics and are classed as contaminants.

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open circuit	(a) A water circuit so designed that water is required in excess of that necessary to replace losses in product and by evaporation due to a loss by free discharge or seepage. (b) A system of crushing or grinding in which oversize material is not recycled.
open flood box	*See* flood box.
open loop control	*See* loop control.
open screening area	*See* effective screening area.
operational capacities plant capacities process capacity	Figures given on the flowsheets to indicate quantities passing various points in the plant per unit time, taking account of fluctuations in the rate of supply and composition (as to size and content of impurity), as follows: (a) *Design capacity*—the rate of feed, defined by limits expressing the extent and duration of load variations, at which specific items of plant subject to a performance guarantee must operate continuously and give the guaranteed results on a particular quality of feed. (b) *Peak design capacity*—a rate of feed in excess of the design capacity which specific items of plant will accept for short periods without fulfilling the performance guarantees given in respect of them. (c) *Mechanical maximum capacity*—the highest rate of feed at which specific items of equipment, not subject to performance guarantees, will function on the type and quality of feed for which they are supplied.
organic efficiency	*See* recovery efficiency.
over-dense medium	Medium of density above that in the dense medium separator, usually produced in the medium solids recovery system and used to maintain the desired density in the separator.
oversize	(a) That portion of the mass of material having a particle size greater than a nominated size. (b) Material in a product having a particle size greater than the separating size.
oversize control screen	*See* screen (h).
oversize in undersize stream	Particles in an undersize stream which are larger than the nominal dimension of the size of separation.
paddle mixer	A horizontal trough conveyor having two non-continuous spirals which form paddles; the shafts are contrarotating and the spirals opposite hand.
particle size analysis	The division of a sample into particle size fractions with defined limits, the proportions of the fractions being expressed as percentages of the total sample (e.g. mass percentage or number percentage).
particle size distribution curve PS distribution curve	A graphical representation of the size analysis of a mixture of particles of various sizes, using an ordinary, logarithmic or other scale.
partition coefficient distribution coefficient	The percentage of a density (or size) fraction recovered in one of the products of a separation (e.g. the reject).
partition curve	A curve indicating for each density (or size) fraction the percentage of it which is contained in one of the products of the separation (e.g. the reject).
partition density (d_p, d_{50})	The separation density corresponding to a partition coefficient of 50 percent, determined from a partition curve (*see also* separation density).
partition factor	*See* partition coefficient.
partition size (S_{50})	The separation size corresponding to a partition coefficient of 50 percent determined from a partition curve (*see also* separation size).
peak design capacity	*See* operational capacities.
percentage open area	The ratio of the total area of the apertures to the total area of the screening medium, e.g. woven wire cloth.
percentage recovery	The amount of a certain constituent in the product expressed as a percentage of that constituent in the feed.
performance curve	Any curve used to show the relation between properties of coal and results of a specific treatment.
phase inversion	Replacement of the film of water covering a coal particle by a film of oil.
pick breaker	A machine for breaking coal by the splitting action of mechanically operated picks.
picking belt picking table	A continuous conveyor (e.g. in the form of a rubber belt or of a steel apron, steel plate or link construction) on which raw coal is spread so that selected ingredients may be removed manually.
pilot plant	A plant of limited capacity but duplicating the operations of a proposed plant so that effectiveness of the designed process may be determined.
pit water mine water	Water from mine workings.
plant capacities	*See* operational capacities.
plant effluent	Surplus water discharged from a coal preparation plant, usually to waste.
plunger jig piston ji	A jig in which the pulsating motion is produced by the reciprocating movement of a plunger or piston.

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pre-coat	A permeable layer covering the medium in a filtering machine to improve clarification of the filtrate.
pressure filter	A filter in which pressure is applied to induce flow of fluid through the filter medium.
pressurized flood box	*See* flood box.
primary cells	*See* cells.
primary reject elevator	A refuse elevator which extracts the first or heavier reject; often situated at the feed end of the jig.
primary screen	*See* screen (j).
probability screening	A method of screening which by making extended use of the probability of a particle passing through an aperture allows sizing at fine sizes to be performed with relatively large apertures.
probable error ecart probable moyen (Epm)	One half of the difference between the densities corresponding to the 75 percent and 25 percent partition coefficients as obtained from the partition curve.
probable performance curve	A performance curve showing the expected results of a coal preparation treatment.
process flowsheet	*See* flowsheet (d).
pulp	A mixture of solid particles and water.
pulp density percent mass solids	The percentage, by mass, of the solids in a pulp. May also be designated as the density of the suspension.
pump sump	A tank into which the circulating water or pulp gravitates and from which it is discharged by means of a pump.
push water	*See* flushing water *and* top water.
rake thickener	Equipment for thickening in which the suspended solids settle in a container of circular section and are delivered mechanically to one or more discharge points by a series of arms revolving slowly around a central shaft. Water overflows at the periphery.
raw coal	Coal which has received no preparation other than possible screening or preliminary crushing.
raw feed coal	Coal supplied to a plant or machine, in which it undergoes some form of preparation.
reagent	Any chemical substance added to the washery circuit for some specific purpose.
reciprocating feeder	*See* feeder (c).
recirculation	The operation in which the whole or part of a product from a process is returned to the feed for the process, e.g. the return of the crushed overflow from a screen to the screen feed for rescreening.
reclaimer	A unit or machine to recover material from a stockpile (*see also* loader, bucket wheel).
reconstituted feed	The composition (e.g. relating to size or density) of the feed to a preparation plant (or to a component part) calculated by combining the properties of the products obtained in the appropriate mass proportions, in contrast to the analysis of the actual feed.
recovery	The mass of a specified material obtained as a product from any operation, expressed as a percentage of the feed material on the same moisture basis.
recovery efficiency	The ratio (normally expressed as a percentage) between the actual yield of a desired product and the theoretically possible yield (based on the reconstituted feed), both actual and theoretical products having the same percentage of ash.
recuperator	A magnetic drum used for magnetite recovery (*see* magnetic separator).
reduction ratio	The ratio of particle size of the feed to particle size of product in a crushing operation.
reference size	The separation size, designated particle size, or control size used to define size analysis of the products of a sizing operation (*see also* separation size).
refuse discharge pipes	Pipes used on some jigs instead of a refuse worm.
refuse extraction chamber	That part of the jig into which the refuse extractor discharges.
refuse extractor	A device used in a jig to remove the reject from the compartments of a jig, operated manually or automatically.
refuse rotor star wheel rotor	A reject gate in the form of a rotary (or star) valve.
refuse worm	A screw conveyor fitted at the bottom of some jigs to collect the fine reject which has passed through the apertures in the screen plate.
regenerated dense medium recovered dense medium	Medium obtained from the medium recovery system and separated (wholly or partly) from contaminating impurities.
reject refuse	The material extracted from the feed during cleaning, for retreatment or discard.
reject elevator refuse elevator	An elevator for removing and draining the reject from a washing appliance.
reject gate discharge shutter	The mechanism of the refuse extractor which may be manually or automatically operated to control the rate of removal of reject from the jig.
relative density	The ratio between the mass of a unit volume of a material and an equal volume of water, each measured under standard conditions.
relative density curve	Any curve obtained from the results of a float and sink analysis by plotting the cumulative percent mass of floats or sinks against the relative density.

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release analysis	A procedure employed in the laboratory to determine the best results possible in cleaning a coal by froth flotation.
relieving deck	A screenplate with large apertures mounted over the screen deck in order to reduce the load and wear theron.
residence time	The mean time for which a unit of material is within a vessel or process.
resonance screen	*See* screen (k).
re-wash (verb)	To re-treat a product in the same or in another cleaning process.
re-wash (noun)	The product from one cleaning process to be re-treated in another.
riffles (table)	The raised portions of the deck of a concentrating table.
rigid hammer crusher	A machine in which size reduction is effected by elements rigidly fixed to a rotating horizontal shaft mounted in a surrounding casing.
rinsing screen	*See* screen (l).
rinsing water	Water used to remove fine particles from larger size particles.
rod deck	A screening surface consisting of loosely held parallel rods positioned at right angles to the flow of material over the screen. Normally used only on high speed vibrating screens.
roll crusher	A machine in which size reduction is effected by causing the material to pass between a rotating roller, generally toothed, and a fixed or spring-loaded plate, or between two or more rollers.
roll screen	*See* screen (m).
rotary air valve	A jig air valve which rotates on a central axis.
rotary breaker Bradford breaker	A rotating perforated steel drum through which passes material of the required size. The oversize material is lifted by flights inside the drum and allowed to fall back so that friable materials break by impact and pass through the perforations. The more competent material may not break and is discharged from the end of the drum.
rougher cells	*See* cells.
run-of-mine coal ROM coal	Coal produced by mining operations, before preparation.
run-of-mine screen	*See* screen (n).
sample	A part of a population collected with the object of estimating some characteristic. It is a portion extracted from a consignment, batch or unit as being representative of it with regard to the characteristic to be investigated.
sampler	Apparatus designed to obtain representative increments from the material being sampled.
scavenger cells	*See* cells.
screen	Any type of perforated surface used to subdivide any material according to the particle size of the constituents. The various types of screens are as follows: (a) *Bar screen*—a stationary inclined screen, comprising longitudinal bars, spaced at intervals, on to which the material to be screened is fed at the upper end. (b) *De-sliming screen*—a screen used for the removal of slimes from larger particles, usually with the aid of water sprays. (c) *Fixed screen*—a stationary inclined or curved panel, commonly of wedge-wire, which is used to remove a large proportion of water and fines from a suspension of coal in water. (d) *Jigging screen*—a screen, or pair of screens, to which a combined horizontal and vertical motion is imparted, normally by a crankshaft and connecting rod, the screen decks being horizontal or inclined at a small angle. (e) *Medium draining screen*—a screen for draining dense medium from the products of a dense medium separator. (f) *Medium recovery screen*—a composite screen for draining and rinsing the products from a dense medium separator to remove adherent medium solids. (g) *Multi-deck screen*—a screening machine with two or more superimposed but separate screening surfaces mounted rigidly within a common frame. (h) *Oversize control screen (guard screen, check screen)*—a screen used to prevent the entry into a machine, of coarse particles which might interfere with its operation. (j) *Primary screen (raw coal screen)*—a screen used to divide coal (usually raw coal) into sizes more suitable for the subsequent cleaning of some or all of them. (k) *Resonance screen*—a screen with a period of oscillation at, or very close to, the the natural period of oscillation of the resilient mounting. (l) *Rinsing screen (spray screen)*—a screen used for the removal of fine solids by spraying, especially for dense medium solids present among, or adhering to, larger particles. (m) *Roll screen*—a screen consisting of a number of horizontal rotating shafts, fitted with elements arranged to provide screening apertures. (n) *Run-of-mine screen*—a screen used for dividing run-of-mine coal into two or more sizes for further treatment or disposal; usually employed to remove the largest pieces for crushing and re-addition to the run-of-mine coal.

(o) *Single deck screen*—a screen having one screening surface, not necessarily limited to one size or shape of aperture.

(p) *Sizing screens (grading screens, classifying screens)*—a screen, or set of screens, normally used for dividing a product (e.g. washed coal) into a range of sizes.

(q) *Slurry screen*—a screen to recover a granular product from a slurry in a coal preparation plant, usually after a preliminary concentration of the solids. It may be equipped with water sprays.

(r) *Trommel screen*—a screen in which the screening surface is formed into a cylinder or frustum of a cone, mounted upon a horizontal or near horizontal rotating shaft or on revolving rollers.

(s) *Vibrating screen*—a screen oscillated either by mechanical or electrical means. The amplitude of movement of the vibrating screen is smaller than that of the jigging screen and its speed of oscillation is higher.

screen cloth screen mesh	A mesh of wires woven to form the apertures.
screen deck screening surface	A surface provided with apertures of specified size for carrying out the operation of screening.
screening	The separation of solid particles of different sizes (with or without the use of water) by causing one component to remain on a surface provided with apertures through which the other component passes.
screenplate	A plate provided with apertures of specified size for use as a screen deck.
secondary cells	*See* cells.
secondary reject elevator	An elevator for removing and draining reject produced in the second stage of the jigging operation.
segregation	The involuntary separation of particles of different physical characteristics.
selective crushing	Crushing in such a manner as to cause one ingredient of the feed to be crushed preferentially to others.
selective flotation	A process for the preferential recovery of a particular ingredient of the coal, e.g. a petrological constituent, by froth flotation.
selective grinding	Grinding in such a manner as to cause one ingredient of the feed to be ground preferentially to others.
separation medium	Dense medium of the density required to achieve a desired separation.
separation density	The effective density at which a separation has taken place, calculated from relative density analysis of the products; commonly expressed as either partition density or equal errors cut-point (density).
separation size	A general term indicating the effective size at which separation has taken place, calculated from a particle size analysis of the product; commonly expressed as either partition size or equal errors size.
settling cone settling tank	A tank used to settle coarse solids from the circulating water.
settling pond tailings dam	A pond, natural or artificial, for collecting the solids from plant effluent. The water may either be disposed of or re-used.
shower box	A water tank with a perforated bottom supported over a screen. The perforations permit the water to discharge at a controlled rate to a false bottom of finely corrugated material so arranged that the water falls as droplets on to the screen.
sieve	Generally—screen of relatively small area. Particularly—screen used in the laboratory for test purposes.
sieve bend	A screening device consisting of a stationary curved panel, commonly of wedge-wire, whereby the finer particles pass with the bulk of the water into the underflow.
single deck screen	*See* screen (o).
sinks	Fractions with a defined lower limit of relative density, defined by the letter 'S', followed by the numerical value of the lower relative density, e.g. 'S 1.80' describes the sinks fraction containing all particles having relative densities greater than 1.80.
size analysis	*See* particle size analysis.
size distribution curve	*See* particle size distribution curve.
size reduction	*See* breakage, comminution, crushing, degradation *and* grinding.
sizing	Separation of a material into products between nominal size limits.
sizing screens	*See* screen (p).
slimes	Extremely fine particles in suspension.
sluice	*See* launder.
slurry	In coal preparation, fine particles concentrated in a portion of the circulating water and water-borne for treatment or disposal.
slurry pond	*See* settling pond.
slurry screen	*See* screen (q).
slurry tower	A tank (usually of concrete) used for the storage and thickening of washery slurries. Its height is such as to permit the flow by gravity of the water and slurry to the appropriate units in the coal preparation plant.

EXHIBIT "11"-Australian Standard 2418, Part 1 - 1980, Terms Relating to Coal Preparation 1980

solid bowl centrifuge	*See* centrifuge, solid bowl.
spigot	The orifice portion of a unit (e.g. the apex of a cyclone) through which the underflow discharges.
splitter box	A receiver fitted with an adjustable device to divert or apportion flow.
spoil bank	A stockpile of reject material. May also refer to waste material (e.g. overburden) from mining operations.
star feeder	*See* feeder (e).
statement of performance	A statement describing the scope and duty of a plant in terms, for example, of the tonnage of coal treated per hour, the processes used, the separations effected and sizes produced; sometimes also used to express the results of plant operation.
stockpile	A reserve of coal stored in the open.
stroke throw	The distance between the extreme positions of an oscillating or vibrating motion, i.e. the stroke is equal to twice the amplitude.
sump	*See* pump sump.
surge bunker	A bunker (hopper) designed to receive a feed at fluctuating rate and to deliver it at some predetermined rate.
suspended matter	Particles of the feed with density equal or close to that of a separating medium, and which are therefore relatively difficult to remove from the separator.
suspension	A mixture of solid particles and water or air in which the solid particles are completely and individually supported, normally by means of an upwardly moving current or with the assistance of mechanical agitation.
swing hammer mill	A machine in which size reduction is effected by hammers loosely fitted to a rotating shaft enclosed in a surrounding casing.
tailings	The fine reject product from flotation, gravity separation, classification, magnetic separation, or other separation processes.
teeter (in) fluidized suspension (in)	The condition of a suspension of solids in an upward-moving current of water or air, whereby the support given to the particles reduces the internal friction between them to such an extent that the suspension acquires fluid or partially-fluid properties.
theoretical yield	The maximum yield (as shown by the washability curve) of a product with a specified percentage of ash.
thickener (clarifier)	*See* rake thickener.
thickening	The concentration of the solids in a suspension with a view to recovering one fraction with a higher concentration of solids than in the original suspension.
thickening cyclone	*See* cyclone (d).
top water transport water	Water introduced with the raw coal feed to assist the transport of material through the jig.
total of correctly placed material	The sum of the masses of material correctly included in the products of a sizing or density separation, expressed as a percentage of the mass of the feed to the separator (and equal to 100 minus the total of misplaced material).
total of misplaced material	The sum of the masses of the misplaced material in the products of a sizing or density separation, expressed as a percentage of the mass of the feed. When three products are made in a single separator, the total of misplaced material will be the sum of the mass wrongly placed in each of the three products, expressed as a percentage of the feed to the separator.
tramp iron	Pieces of magnetic metal, metallic equipment or machine parts which have become accidentally mixed with the run-of-mine coal.
transport water	*See* top water.
trash	Extraneous material associated with the run-of-mine coal, e.g. wood, metal, plastics material.
trommel screen	*See* screen (r).
tromp curve	*See* error area.
tromp cut-point	*See* partition density.
trough washer	*See* launder washer.
true middlings	Comparatively high ash particles so nearly homogeneous that the quality cannot readily be improved by crushing and recleaning.
'U' tube	A pipe with two vertical legs normally arranged with head and discharge boxes having provision for differential level and adjustment to induce flow at a controlled velocity. The rising leg is normally fitted with primary and repeater differential pressure cells or an equivalent sensing component in the heavy medium, relative density control loop.
underflow, screen	That portion of the feed material which has passed through the apertures in a screen deck.
underscreen water backwater	Water which is fed into the cells of a jig below the level of the screenplate.
undersize	(a) That portion of a mass of material having a particle size less than a nominated size. (b) Material in a product having a particle size less than the separation size.

EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
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undersize in oversize stream	Particles in a screen oversize stream which are smaller than the nominal dimensions of the screen apertures.
upgrade	*See* beneficiate.
upward current washer	A washer in which separation takes place under the influence of an upward current of water or dense medium.
useful area of a screen	*See* effective area of a screen.
vacuum filter	*See* disc filter *and* drum filter.
vacuum flotation	A process in which the pulp is subjected to a reduced pressure causing dissolved air to form the bubbles necessary for froth flotation.
vibrating screen	*See* screen (s).
vibratory feeder	*See* feeder (f).
vortex	In a cyclone this refers to the swirling pulp surrounding the air core formed along the axis of the unit.
vortex finder	An open cylinder arranged axially inside a cyclone to control separation.
wash	*See* beneficiate.
washability	The amenability of a coal to improvement in quality by density separation processes.
washability curve	Any curve obtained from the results of a float and sink analysis permitting the theoretical yield of floats or sinks to be read off. There are four main types of washability curve, as follows: (a) The characteristic ash curve. (b) The cumulative floats curve. (c) The cumulative sinks curve. (d) The relative density curve.
waste water	Excess water allowed to run to waste from the water circuit.
water circuit	The complete system of pipelines, pumps, sumps, tanks, troughs and accessories used for the circulation of water in a coal preparation plant, including the water treatment plant.
water only cyclone	*See* cyclone (e).
water washing cyclone	*See* cyclone (e).
wedge-wire deck **wedge-wire screen**	A screen deck comprising units of wedge-shaped cross-section spaced from each other at a fixed dimension.
weighted flowsheet	*See* flowsheet (e).
weightometer	*See* belt weigher.
weir	A plate or dam (over which the liquid must flow) to control the level of the liquid.
wet cleaning	*See* cleaning.
wet screening	*See* screening.
wetting agent	A reagent to reduce the interfacial tension between a solid and a liquid and so to facilitate the spreading of the liquid over the solid surface.
Wolf cut-point	*See* equal errors cut-point.
yield	The mass of product obtained from any operation, expressed as a percentage of the feed material on a defined basis.
yield loss	The difference between the actual yield of product and the yield theoretically possible (based on the reconstituted feed) of a product with the same properties (e.g. percentage of ash and moisture).

EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
to Coal Preparation 1980

PUBLICATIONS OF THE ASSOCIATION

A list of Australian Standards may be purchased or inspected at any office of the Association.

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- Standards Council of Canada
- Standards Institution of Malaysia
- Singapore Institute of Standards and Industrial Research
- American National Standards Institute
- Japanese Industrial Standards Committee
- International Organization for Standardization
- International Electrotechnical Commission

EXHIBIT "11"-Australian Standard
2418, Part 1 - 1980, Terms Relating
to Coal Preparation 1980

STANDARDS ASSOCIATION OF AUSTRALIA

The Standards Association of Australia was founded in 1922 as the Australian Commonwealth Engineering Standards Association, and was incorporated by Royal Charter in 1950.

The principal function of the Association is to prepare and publish Australian Standards and to promote their adoption. Standards are in the form of specifications for materials and products, codes of sound or safe practice, methods of testing, nomenclature, etc. They are prepared by representative committees which co-ordinate manufacturing capacity and production efficiency with the users' reasonable needs. They seek to achieve fitness for purpose, simplified production and distribution, replacement interchangeability, and adequate variety of choice without wasteful diversity.

Australian Standards are prepared only after a full enquiry has shown that the project is endorsed as a desirable one and worth the effort involved. The work is based on voluntary agreement, and recognition of the community of interest of producer and consumer.

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EXHIBIT "11"-Australian Standard 2418, Part 1 - 1980, Terms Relating to Coal Preparation 1980

EXHIBIT "12"-Affidavit of Arthur Noel Pritchard dated 24.5.83

No. 2313 of 1982

IN THE SUPREME COURT
OF WESTERN AUSTRALIA

IN THE MATTER of an Agreement between LANGLEY GEORGE HANCOCK, ERNEST ARCHIBALD MAYNARD WRIGHT, WRIGHT PROSPECTING PTY. LTD., HANCOCK PROSPECTING PTY. LTD, two other companies and HAMERSLEY IRON PTY. LIMITED

BETWEEN:

HAMERSLEY IRON PTY. LIMITED	Plaintiff
AND	
LANGLEY GEORGE HANCOCK	First Defendant
ERNEST ARCHIBALD MAYNARD WRIGHT	Second Defendant
HANCOCK PROSPECTING PTY. LTD.	Third Defendant
WRIGHT PROSPECTING PTY. LTD.	Fourth Defendant
L.S.P. PTY. LTD.	Fifth Defendant
THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED	Sixth Defendant

AFFIDAVIT

I, ARTHUR NOEL PRITCHARD of 5 The Lee, Middle Cove in the State of New South Wales, Manager, make oath and say as follows:

1. (a) I am Manager, Consultancy Services and Marketing Manager, South-East Asia for Allis Chalmers Australia Limited ("Allis Chalmers"). I have worked on engineering matters in relation to the mining industry for 45 years and throughout that period have been involved with the design and application of material handling and mineral processing plants and particularly involved with screening processes.

EXHIBIT "12"-Affidavit of Arthur Noel Pritchard dated 24.5.83

A.N. Pritchard

(b) In 1937 I completed an engineering apprenticeship with the New South Wales Railways. From 1937 to 1949 I was a design draftsman with Alluvial Mining Equipment Ltd., which designed complete gold and tin dredging equipment and plants for use in Australia, New Zealand and Malaysia. The processes used in those plants were heavily dependent on screening. From 1949 to 1954 I worked as design engineer with the Colonial Sugar Refining Company Limited at Rhodes, New South Wales in the design and engineering of chemical processing plants. Again I was involved with screen application.

(c) In 1954 I joined Gibson Battle & Co. Pty. Ltd. ("Gibson Battle"), a general engineering company based in Sydney, as a design engineer. Gibson Battle had a very extensive business in the design, engineering and commissioning on a turnkey basis of material handling, crushing and screening facilities at many large mineral processing plants throughout Australia. It was a licensed manufacturer of Tyler vibrating screens. Whilst at Gibson Battle, both as design engineer and later as chief draftsman, I became involved in work on many and varied screening operations including, in addition to processing in areas such as aggregate and coal handling plants, screens for water intakes at power stations.

(d) I moved to Allis Chalmers in 1961 as Sales Engineer (Screening). In 1967 I became Product Manager (Screening) and in 1973 became General Manager (Products) and Marketing Manager, South East Asia. I took up my present position in 1977. In all these capacities I was closely involved with screens, indeed more so than with any

A.N. Pritchard

other product. My initial involvement was in application and sales of vibrating screens, including special feature design, but I have increasingly specialised in the application and selection of vibrating screens for fine screening and dewatering requirements, all in the mineral industry.

(e) Allis Chalmers is the leading manufacturer of vibrating screens in Australasia, having approximately ninety percent of the vibrating screen market. Vibrating screens are by far the most practicable and widely-used screens for mineral processing in Australia. Allis Chalmers supplies or has supplied screens and advice on equipment size, water requirements, preparation of feed and screening application to most major mining companies in Australia, including Comalco Ltd., Broken Hill Pty. Co. Ltd., MIM Holdings Ltd., Mt. Newman Mining Co. Pty. Ltd., Goldsworthy Mining Ltd., Robe River Ltd., Savage River Mines joint venture, Alcoa of Australia Ltd., Western Mining Corporation Holdings Ltd., EZ Industries Ltd., Cleveland Tin Ltd., Renison Goldfields Consolidated Ltd. and Agnew Mining Ltd. and to Bougainville Copper Ltd. and the OK Tedi joint venture in Papua New Guinea as well as to the Plaintiff.

(f) I have been associated in varying degrees with screening aspects in every major iron ore mine and iron ore processing plant erected in Australia since the Second World War and have visited the mines of all the iron ore producers listed in sub-paragraph (e) and the processing plants at those mines. I last visited Tom Price in February, 1983.

EXHIBIT "12"-Affidavit of Arthur Noel Pritchard dated 24.5.83

J.P.

A.N. Pritchard

2. I have been asked to advise the Plaintiff in relation to these proceedings and I have read, and ask leave to refer to, the Affidavit of Colin Roy Langridge sworn on 2nd September, 1982, the Affidavits of Niles Earl Grosvenor and Peter Forbes Booth both sworn on 27th October, 1982 and the Affidavit of Alban Jude Lynch sworn on 22nd day of May 1983 all filed herein. I have also read the exhibits to each of those Affidavits, including the Agreement which is "Exhibit CRL 1".

3. The use of the expression "beneficiation" to describe the whole secondary phase of treatment between mining and smelting is not uncommon in the iron ore processing industry. In this sense it takes in all activities from the primary crusher at the mine tiphead through to stockpiling. During the secondary phase of treatment any treatment of the ore that is considered as essential preparation for achieving improvement of the product, particularly involving concentration by heavy media or flotation, is included in the category of "beneficiation".

4. I agree with the conclusions expressed by Dr. Lynch in paragraphs 9 and 10 of his Affidavit and with the reasons he gives for them, in particular that "crushing and screening" usually refers and referred in 1962 to a dry process, that the scrubbing effects at Tom Price are distinct from the screening and that water is introduced into the process to prepare the feed for later concentration in the drums, cyclones and WHIMS. Scrubbing begins in the pulping box. I also agree that the pulping box would not have been designed the way it is if it were not for the purpose of maximising the scrubbing effect of the water

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before the feed moves on to the screen deck. Like Dr. Lynch I am not aware of any iron ore processing plant where a wet process was in use in 1962 or is in use now solely as an adjunct to crushing and screening without some further process in view.

5. Another way of looking at the problem is to appreciate that a screen is designed to size ore, not to break it up. That is done by a crusher. Because the product from a preparatory screen before a heavy media concentration process must be clean as well as of a specific size it is necessary to add a further step: water is introduced to clean the ore. The water may assist the sizing function to take place but its main purpose is to perform the cleaning function required.

6. In 1962 sieve bends were a relatively new product developed by a Netherlands company, Dutch State Mines. They were not called "screens". They work on the principle that water and particles in it travelling very rapidly down a concave perforated slope are driven outwards allowing them to pass as fine pulp through the surface apertures in the slope assisted by centrifugal force. The sizing function is only a rough one. The use of sieve bends is to remove excess water and the finest particles suspended in it. A sieve bend is quite different from a vibrating screen, which depends on natural gravity and "throw" (upward and forward movement) caused by vibration to break the surface tension between particles of feed and the deck surface and to present the particles to the apertures with the desired frequency and in stratified form.

7. I ask leave to make the following particular observations on Mr. Grosvenor's Affidavit:

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(a) Paragraph 10

Sentence 2. If water is added to the feed in a pulping box it achieves the same effect in principle as if the feed were passed through a scrubber prior to screening. The only difference is one of degree and the choice between a pulping box and a scrubber will depend on the type of ore involved.

Sentence 3. The process of screening with the addition of water is not always called wet screening. It is often called "washing and screening" or just "washing", in the loose sense of "washing" to which Dr. Lynch refers in paragraph 6 of his Affidavit. The expression "wet screening" probably evolved because of the physical proximity of the two processes in the process circuit, but they are distinct. The pulping box would be just as effective if it were located several hundred metres before the screen in the operating circuit. This comment also applies to sentences 8 and 9 of paragraph 12 of Mr. Grosvenor's Affidavit.

Sentence 5. If thorough cleansing of the ore for later concentration is desired it is essential to slurrify or pulp the ore prior to screening.

(b) Paragraph 12

Sentence 5. The preferable screen for use in conjunction with scrubbing is a horizontal screen operating with straight line motion rather than circular motion as for an inclined screen. When

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scrubbing is not required screening is normally performed on an inclined screen with circular motion. The screens referred to in paragraphs 9, 10 and 11 of Mr. Langridge's Affidavit are examples of the former; the scalping screens referred to in paragraph 8 thereof and the screens in the Plaintiff's High Grade Ore facility at Tom Price are examples of the latter.

Sentences 6 to 7. The breakdown of contaminants achieved by scrubbing cannot be achieved by screening alone and screening takes place after scrubbing begins in the pulping box. The latter does not "come about" as part of screening. It is a deliberate process aimed at a different physical result.

(c) Paragraph 14

Sentence 3. In my opinion the "wetting" in the pulping box followed by spraying and screening makes the process washing and screening or, more technically, scrubbing and screening.

(d) Paragraph 20

Sentence 3. I do not agree that the words "crushing" and "screening" either now or in 1962 would adequately or accurately describe a sizing and cleaning process for the purposes of later beneficiation, such as the process at Tom Price with which these proceedings are concerned. I do agree that they would, both now

EXHIBIT "12"-Affidavit of Arthur Noel Pritchard dated 24.5.83

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and then, perfectly describe a dry coarse size reduction and grading process, such as the High Grade Ore facility at Tom Price.

With reference to Mr. Booth's Affidavit, I ask leave to make the following particular comments:

(a) Paragraph 8

Sentence 2. Nearly all screens operating in the iron ore industry in Australia are and were in 1962 vibrating screens.

Sentences 3, 4 and 5. In my experience, in iron ore processing, the decision to wash or scrub as well as to screen depends on whether that is to be followed by a wet concentration process. Either water is required for the later concentration process or it is not. If it is required but is not available, the process cannot be installed. If it is not required but is available, it is unlikely to be used.

(b) Paragraph 9

Sentence 2. Water is an expensive and complicating component. It is only added to achieve a desired result. It is not an "optional extra" that one would add lightly. I can agree with the words "efficiency of separation" only if they refer to the separation of gangue from mineral in the heavy media drums and cyclones; but even then I would have to say that, if no cleaning were done by the water, heavy media separation would not work.

J.P.

A.N. Pritchard

(c) Paragraph 10

Sentences 2 and 3. I refer to and adopt paragraph 6 of Dr. Lynch's Affidavit and repeat my comment above on the expression "efficiency of separation".

(d) Paragraph 11

Sentence 1. At Tom Price the water preconditions the feed for later concentration in the drums, cyclones and WHIMS. It is only incidental that it also assists passage through the screen.

(e) Paragraph 13

Sentence 4. If the contaminants separate only partly, the treatment would not be effective enough to prepare the feed for the heavy media process. There is some degree of tolerance but the separation must always be thorough.

(f) Paragraph 14

Sentences 3 and 4. Screening alone is not enough. There must be cleaning as well, but there cannot be efficient cleaning at the final preparation screens unless there has been scrubbing earlier.

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J.P.

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(h) <u>Paragraph 16</u>

<u>Sentence 3</u>. I agree with Dr. Lynch's comment in the last sentence of paragraph 9 of his Affidavit.

SWORN by the said ARTHUR)
NOEL PRITCHARD at NORTH SYDNEY.
in the State of NEW SOUTH WALES.
this 24TH day of)
MAY. 1983.)

A.N. Pritchard

Before me: RONALD FRANCIS DIXON.

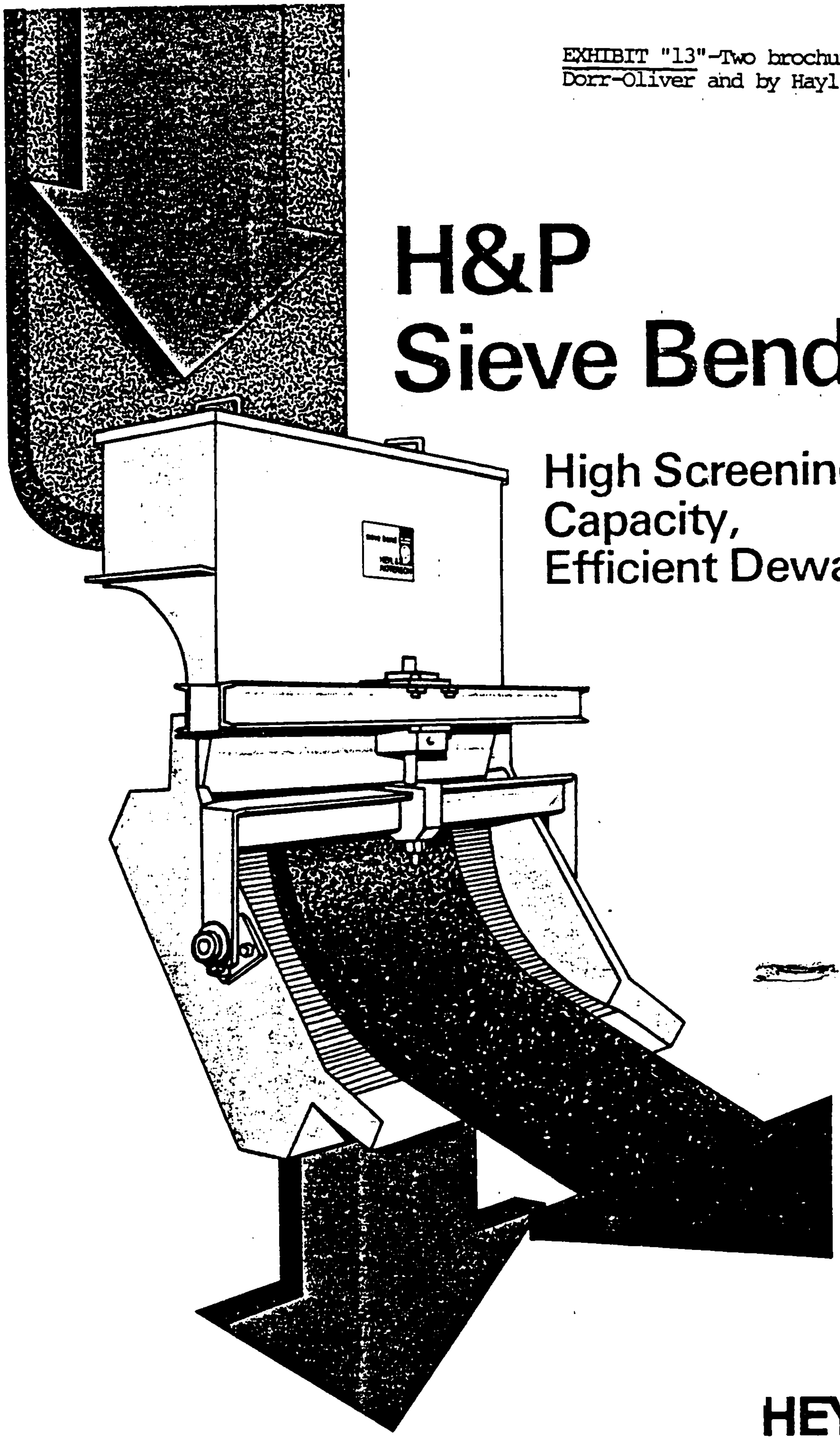
Dixon

A Justice of the Peace

Filed on behalf of the Plaintiff.

<u>EXHIBIT "12"</u>-Affidavit of Arthur
<u>Noel Pritchard</u> dated 24.5.83

EXHIBIT "13"-Two brochures by
Dorr-Oliver and by Hayl & Patterson



H&P
Sieve Bends:

High Screening
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EXHIBIT "13"-Two brochures by
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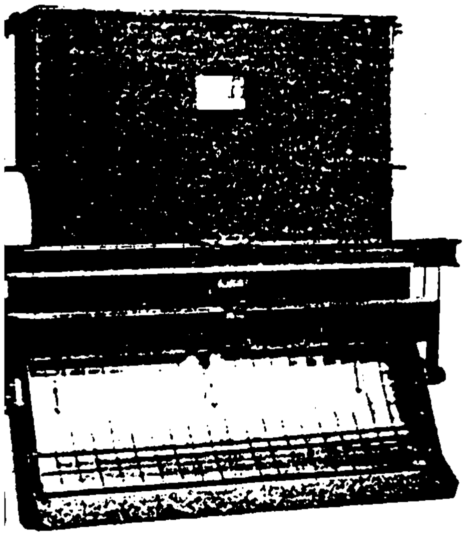
The H&P Sieve Bend



The Heyl & Patterson Sieve Bend offers an economical means for high capacity classifying and dewatering to the Coal Industry. Patterned after the original Dutch State Mines type, and manufactured by agreement in the United States, the basic design has been refined since it was first introduced in 1953.

Simplicity and performance make the H&P Sieve Bend a logical choice for any size dewatering/classifying application. The following paragraphs tell why.

Low Cost Operation

Prep plant operators will appreciate the patented Sieve Bend design. Simplicity is its greatest advantage. It requires no connected horsepower, occupies a limited amount of space, requires a minimum of support structure, and practically no maintenance. As a stationary screen, the H&P Sieve Bend requires no permanently assigned operator, and is without the noise and vibration customarily associated with conventional screening operations.

Periodic reversal of the Sieve Bend screen assures consistant cutting of slurry layers and extends screen life. When wires are worn to the point where screenings become too coarse, the worn screen is easily removed and a new one installed in less than an hour.

Design & Operation

Coal slurry fed at near zero pressure enters the feedbox and passes over a series of baffles which spread the slurry to provide even distribution across the entire width of the deck. Dropping from the last baffle, slurry is fed tangentially to the screen, separating the solids to a predetermined particle size, delivering a dewatered overproduct and a dilute effluent.

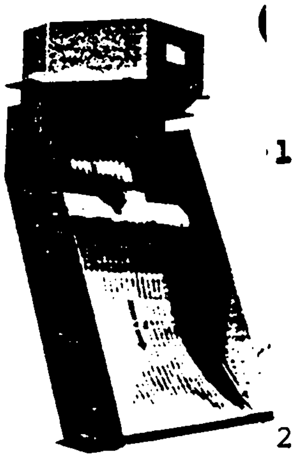
A full stream of coal slurry flowing over the Sieve Bend decreases in depth in increments of about one-quarter the slot width each time it passes a slot. For instance, if a slot width or screen opening being shaved off by each wire is about ¼ mm, this ¼ mm thick cut can transport only up to ½ mm size particles. Therefore, plus ½ mm solids pass over the screen deck. The result is an efficient separation of feed solids at a size considerably smaller than the opening in the Sieve Bend.

The unique screening action of the H&P Sieve Bend extends the practical application of screening to much finer coal sizes without any danger of blinding.

The effluent of the Sieve Bend flows into the effluent chamber from where it is piped for further processing. The cake is discharged over the lip of the Sieve Bend.

Different slot widths in the Sieve Bend produce various particle separations. Standard screen sizes are available from ¼ mm to 2 mm.

The curved Sieve Bend section is mounted in a structural frame and clamped in place between two plates. This design permits 100 percent utilization of the screening area ar effectively prevents oversized solids from entering the effluent.



Two stage Sieve Bend, available in combinations of widths and screen radii.

Capacity

Two important factors influencing the capacity of the H&P Sieve Bend are the free screening area and the velocity of the feed slurry. When making a separation of ½ mm, the H&P Sieve Bend produces an effluent of up to 65 GPM per square foot of Sieve Bend area, far exceeding most conventional screening methods.

Application

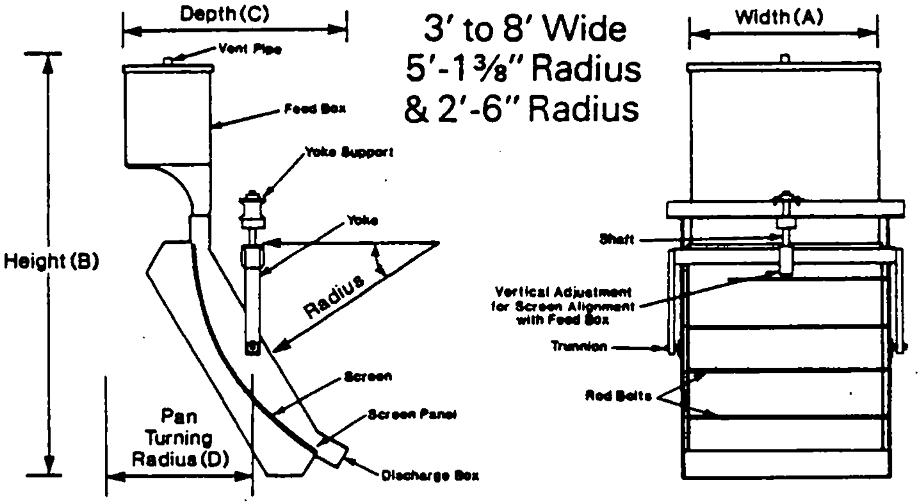
The H&P Sieve Bend can successfully be used in many applications in preparation plants where fine coal (minus ½ in.) is wetted and processed.

The H&P Sieve Bend serves:

- to supplement or even replace sludge tanks or settling cones,

Conventional Sieve Bend

3′ to 8′ Wide
5′-1⅜″ Radius
& 2′-6″ Radius



Nominal Dimensions

A		B	C	D		
Screen				Pan		
Radius	Width	Height	Depth	Turning Rad.	Weight	Cap.
5′-1⅜″	3′	8′-11″	5′-0″	3′- 6″	1300	200 to 2400 GPM of Slurry
	4′	8′-11″	5′-0″	3′- 9″	1500	
	5′	8′-11″	5′-0″	4′- 1″	1900	
	6′	8′-11″	5′-0″	4′- 5″	2100	
	7′	8′-11″	5′-0″	4′- 9″	2400	
	8′	8′-11″	5′-0″	5′- 2″	2800	
2′-6″	3′	6′- 7″	3′-7″	2′- 5″	1000	
	4′	6′- 7″	3′-7″	2′- 9″	1200	
	5′	6′- 7″	3′-7″	3′- 3″	1500	
	6′	6′- 7″	3′-7″	3′-10″	1700	
	7′	6′- 7″	3′-7″	4′- 1″	1900	
	8′	6′- 7″	3′-7″	4′- 6″	2100	

EXHIBIT "13"-Two brochures by Dorr-Oliver and by Hayl & Patterson

- to dewater refuse from concentrating tables,
- as a scalping unit for dressing water for concentrating tables,
- to dewater and classify centrifuge feed or to perform as a "tell-tale" screen for the effluent,
- to prepare froth flotation feed or to scalp froth tailings to recover coarse clean coal,
- and, to classify or dewater feed to vibrating screens, relieving overload conditions and improve screening efficiency.

dvantages of the H&P Sieve Bend

w Operating Cost: Lack of moving parts and negligible maintenance costs minimize perating expenses. The H&P Sieve Bend quires no assigned operator or supervisor.

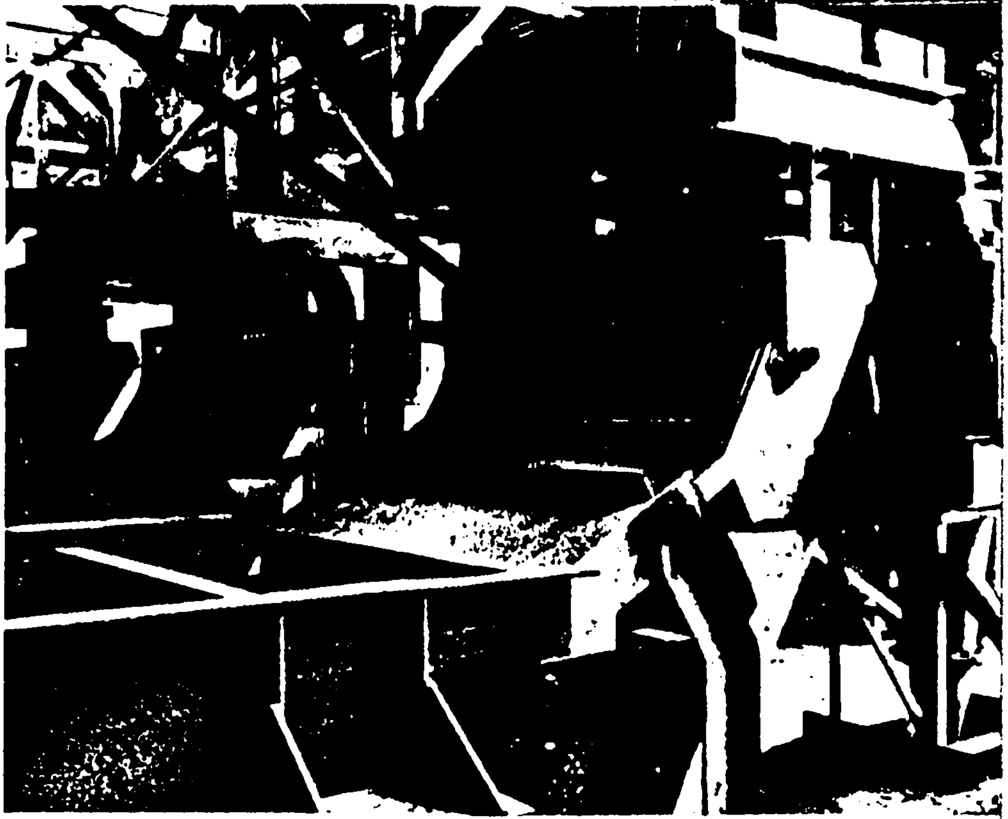
eversible Screen: Means longer periods of peration. Longer screen life means lower osts too.

mplified Design: Lower initial costs, no oving parts, light weight, minimum space nd support structure requirements make e H&P Sieve Bend easy to install in isting plants.

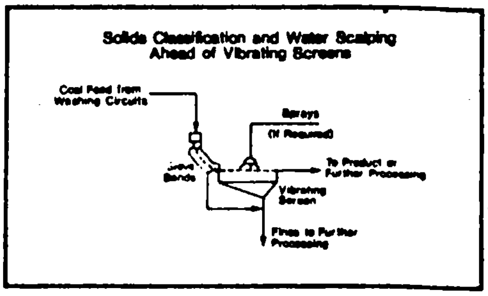
uiet: No moving parts means no vibration nd low noise levels.

ficient, High Capacity: Works with the est sizes. Capacities exceed those of any onventional screening method.

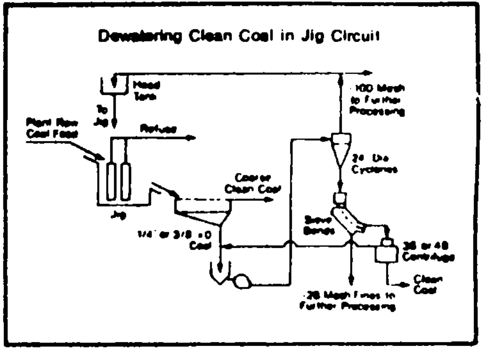
exible: A wide variety of sizes and screens e available to meet the requirements of most any installation.



Bank of H&P Sieve Bends in preparation plant dewatering slurry ahead of vibrating screens

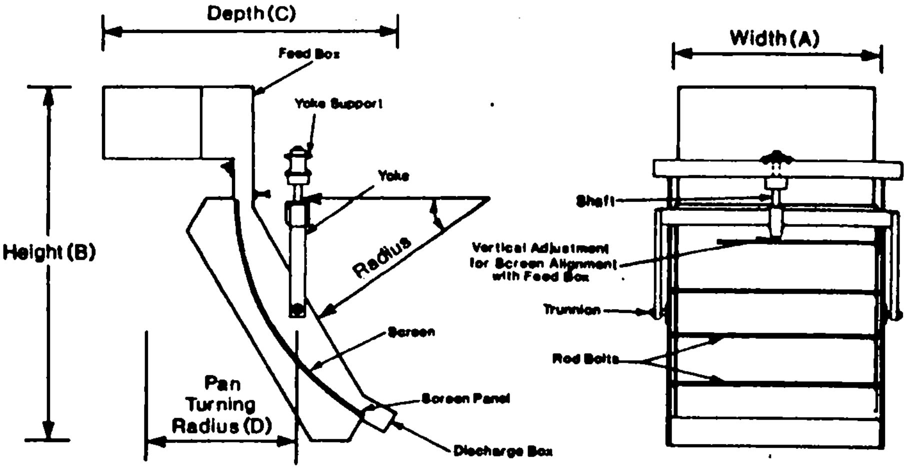


Solids Classification and Water Scalping Ahead of Vibrating Screens



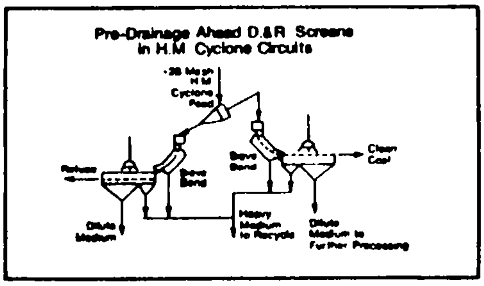
Dewatering Clean Coal in Jig Circuit

Low-Head Sieve Bend

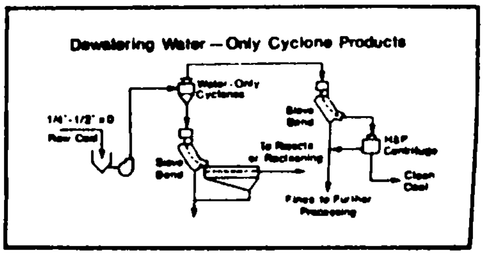


Nominal Dimensions

A		B	C	D		
Screen				Pan		
Radius	Width	Height	Depth	Turn Rad.	Weight	Cap
5'-1¾"	3'	7'-5"	5'-10"	3'-6"	1300	200 to 2400 GPM of Slurry
	4'	7'-5"	5'-10"	3'-9"	1600	
	5'	7'-5"	5'-10"	4'-1"	1800	
	6'	7'-5"	5'-10"	4'-5"	2000	
	7'	7'-5"	5'-10"	4'-9"	2300	
	8'	7'-5"	5'-10"	5'-2"	2600	
2'-6"	3'	5'-0"	4'-7"	2'-5"	900	
	4'	5'-0"	4'-7"	2'-9"	1100	
	5'	5'-0"	4'-7"	3'-3"	1400	
	6'	5'-0"	4'-7"	3'-9"	1600	
	7'	5'-0"	4'-7"	4'-1"	1800	
	8'	5'-0"	4'-7"	4'-6"	2000	



Pre-Drainage Ahead D.&R. Screens in H.M. Cyclone Circuits



Dewatering Water-Only Cyclone Products

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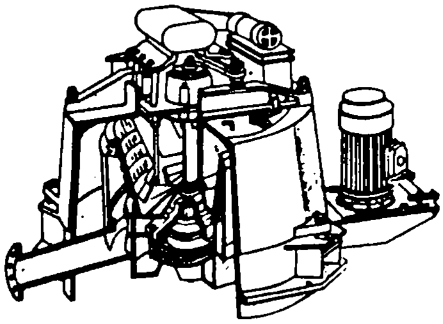
Heyl & Patterson…Proven Performer

leyl & Patterson has been a pioneer de-igner and builder of processing equipment nd plants for many years. H&P plants and equipment have proven their reliability and superior performance in many industrial processing applications.

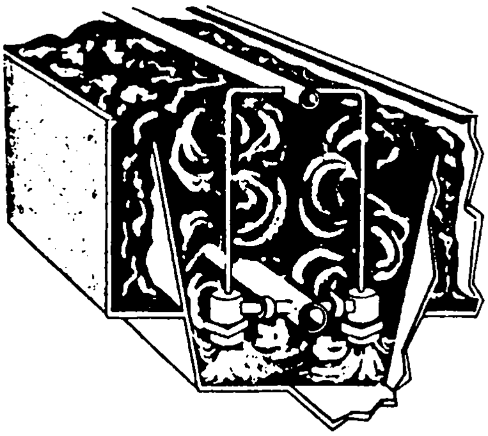
H&P Centrifuges: HP-48 Hurricane & HP-36 Reineveld

iiving you the lowest moisture obtainable y mechanical methods at the lowest cost er ton, Heyl & Patterson Centrifugal Dry-rs have been setting records for high re-overy of both coarse and fine products. IP-48 Hurricane & HP-36 Reineveld Cen-rifugal Dryers are:

- Manufactured for all feed tonnages, with capacity to handle surges up to 250 tph.
- Designed for simplified maintenance and reduced operating cost. All parts are readily accessible.
- Operated at uniform frequency and constant force of vibration for reliable performance.



H&P High Energy Cyclo-Cell Offers Trouble-Free Flotation



The superior performance of the patented Heyl & Patterson Cyclo-Cell, a flotation system, gives you exceptional recovery of quality products with dependable, trouble-free flotation as well as other advantages.

Unequaled simplicity: No moving parts. Vortex chamber provides abundant aeration and agitation.

Low horsepower requirements: Operates effectively with minimum power consumption.

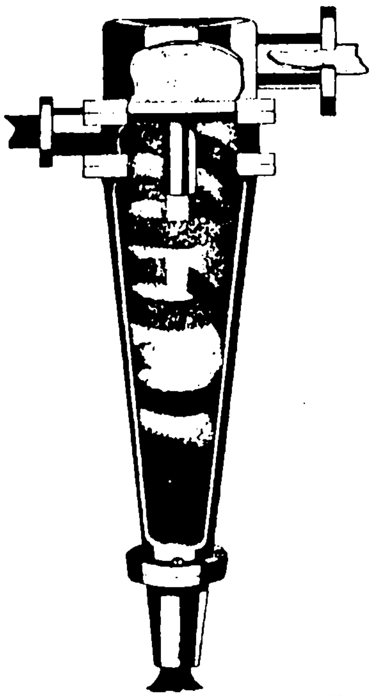
Low installation cost: Simple supporting structure permits easy installation, and cells can be stacked to reduce floor space.

Low maintenance cost: Life expectancy of the low-cost Refrax®Ceramic Vortex Chamber is 4-5 years of continuous service.

Instant start-up: Starts up readily under load without peak power requirement.

H&P Cyclones: Versatile Processors

Pioneered in 1947, H&P Cyclones are the coal industry leader for thickening, separating and classifying chores. A complete line of WATER-ONLY and HEAVY MEDIUM CYCLONES are also available. Heyl & Patterson Cyclones are offered in standard 3, 8, 14, 24 and 30 inch sizes, constructed of Ni-Hard, Ceramic or Elastomers. Flow capacities range from five to 4000 G.P.M. per cone at operating pressure drops of five to 40 P.S.I. H&P Cyclones can handle particle sizes up to two inches. Units can be provided in manifolds or clusters to suit plant layout.



Give Us A Call…

Heyl & Patterson's years of experience in engineering, designing, fabricating and installing materials handling plants and equipment give us unparalleled experience in making sound recommendations for your needs. Our highly skilled engineering staff is always available to analyze and discuss your requirements. Give us a call.

WE THINK SYSTEMS

HEYL & PATTERSON
ENGINEERS AND CONSTRUCTORS

Heyl & Patterson, Inc., 250 Park West Dr., P.O. Box 36, Pittsburgh, Pa. 15230, 412/788-6900
1010 Young St., P.O. Box 1028, Charleston, W. Va. 25324, 304/342-5146

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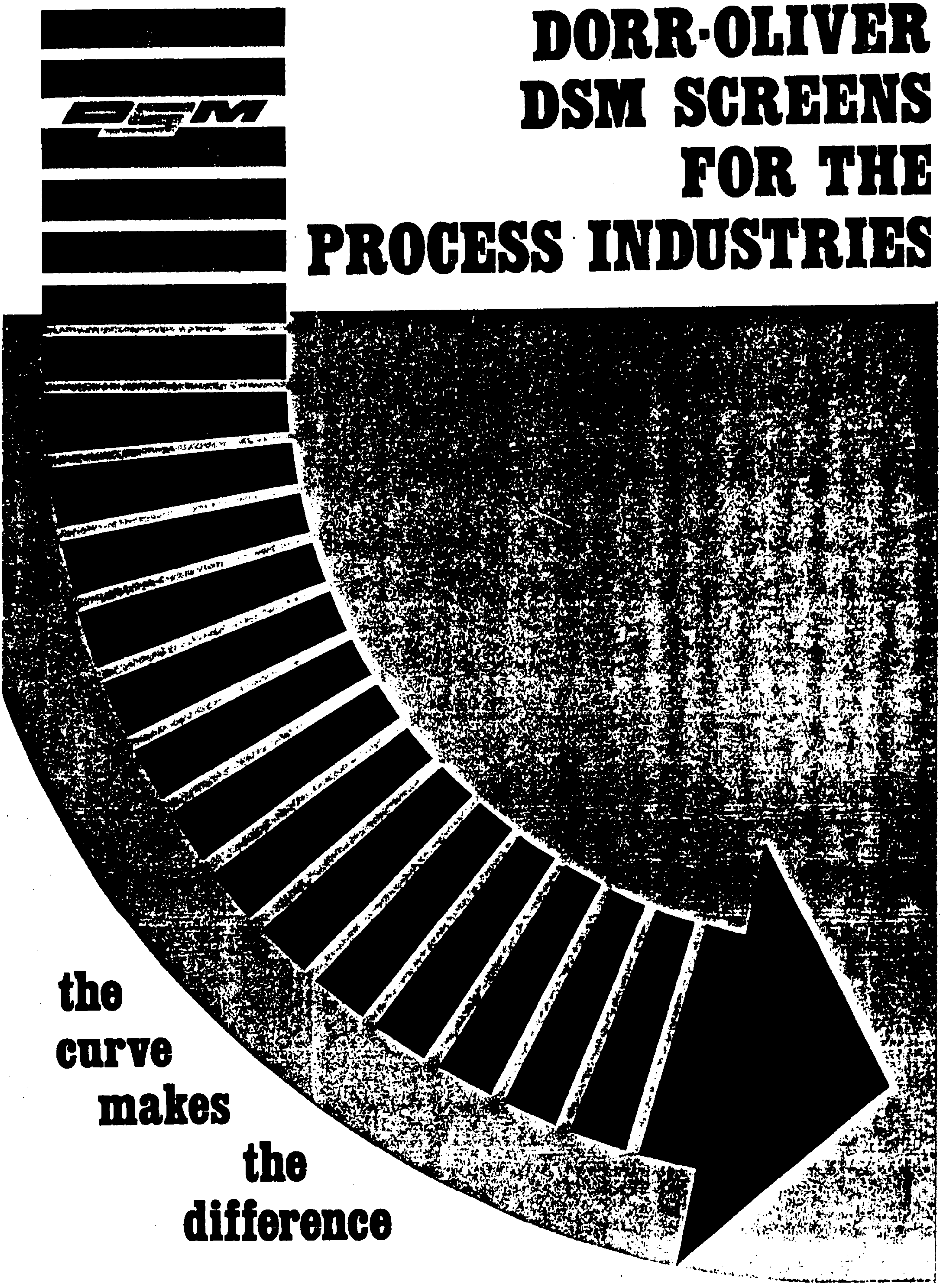

DORR-OLIVER DSM SCREENS FOR THE PROCESS INDUSTRIES

the curve makes the difference

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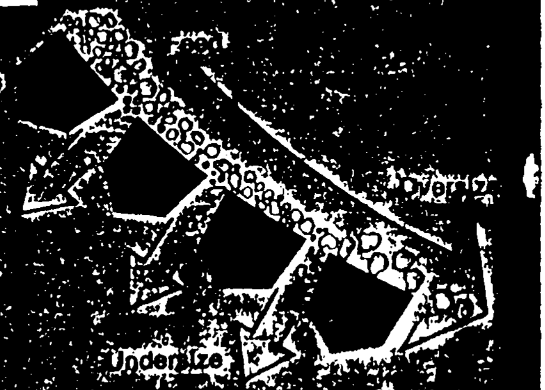
Here's how the DSM works...

The DSM is a rugged, stationary screening [illegible] of the screen. The [illegible] material continues to flow across the [illegible] the continuously curved surface [illegible] necessary centrifugal force [illegible] a high capacity, efficient separation without blinding and a well-dewatered coarse size.

the
curve
makes
the
difference

The continuously curved surface design, unique to the Dorr-Oliver DSM Screen, together with [illegible] velocity across the surface, provides a centrifugal force which holds the slurry against the screen surface constantly.



High Capacity

The DSM handles extremely large flow volumes per unit of screening area because of the centrifugal force developed by use of the continuously curved surface coupled with the proper velocity of material across the screen. This high unit capacity means less equipment to do the job.

Non-clogging

Since the size of separation is determined by the thickness of the layer of material sliced off, the DSM design eliminates blinding and therefore costly cleaning costs. The elimination of blinding also insures more complete recovery of desired mesh of separation and better recovery of valuable products.

Permanent Screen Media

The rugged wedge bar screen provides a permanent screening media, eliminating costly screen replacements. The permanent screening [illegible] eliminates possible contamination of undersize with oversize by screen breakage [illegible] preventing loss of valuable product. [illegible]

No Moving Parts

[illegible]

Low Space Requirements

[illegible]

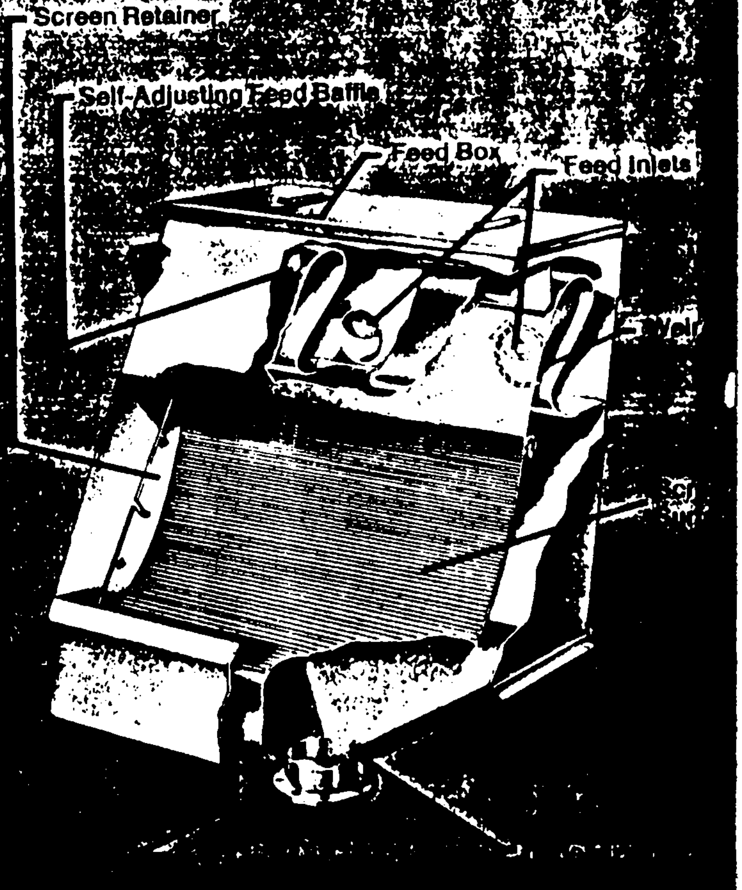


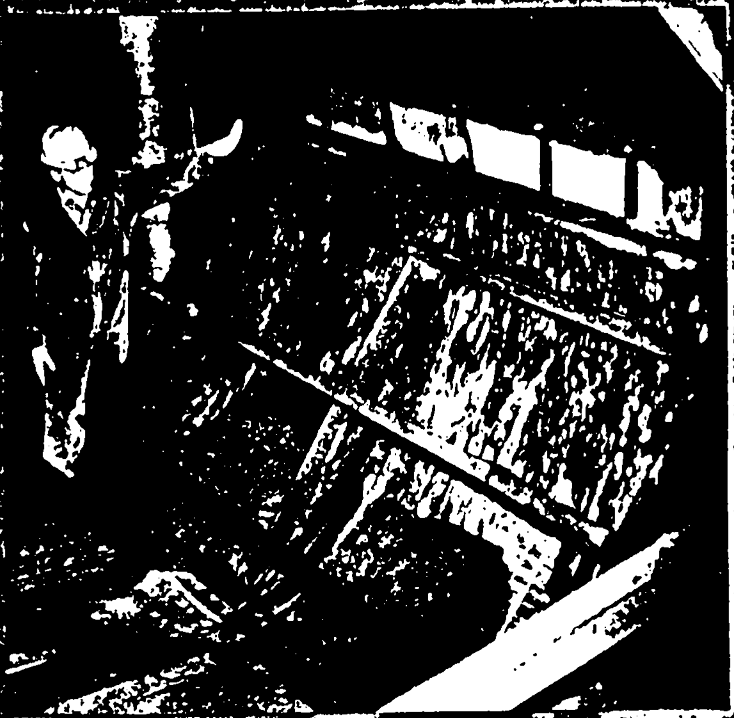
EXHIBIT "13"-Two brochures by
Dorr-Oliver and by Hayl & Patterson

and here's where the DSM is working

Food Processing

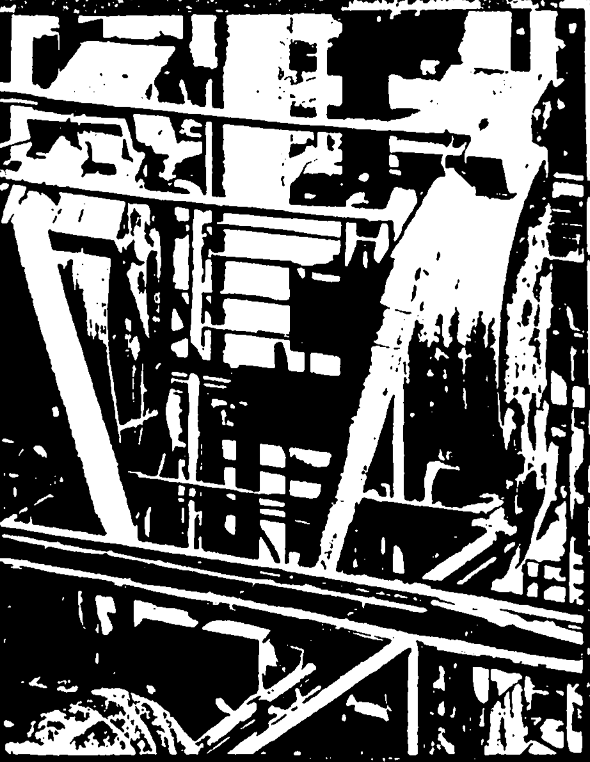
Starch, sugar, distillage, canning by-products, vegetable waste, citrus fruit, potatoes, peas and beans, fish, poultry products, meat by-products and spices.

Mineral Processing



Iron ore, copper, phosphates, potash, coal, alumina, lime, sand, cement and kaolin.

Chemical Industry



Pulp and Paper

Waste Treatment

[illegible]

WESTERN AUSTRALIA

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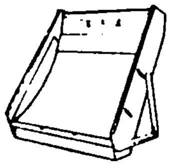
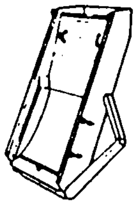
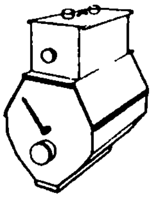
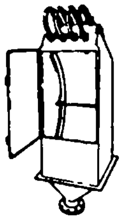
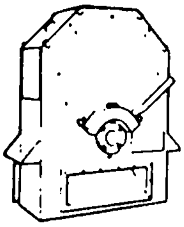
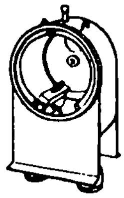
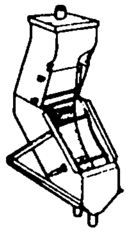
Model	Capacity per ft. of screen width (gpm)	Standard width (ft)	Range of separation (mesh)	Typical applications
 45°	30-200	2, 4, 6	8-65	Thickening, deckering, flume water, fruit and vegetable wastes.
 50°	30-150	2, 4, 6	8-48	Phosphates, potash, ammonium sulphate, steeped grain dewatering, fruit & vegetable processing, alumina.
 60°	30-200	4	8-48	Iron ore, copper ore, sand, cement.
 120°	50-200	2, 4, 6	100-325	Starch fiber washing, fiber recovery, spent grain press liquor, vegetable fine fiber waste, paper-pulp fiber screening, deckering, crystal dewatering.
 270°	100-200	1½	100% minus 50 mesh	Cement slurry at 65% solids.
 300°	50-200	2/3	48-325	Stillage, raw-sugar melt liquor, fiber removal from starch, fiber removal from waste activated sludge.
 RAPIFINE	30-100	2	48-325	Taconite at approx. 90% minus 325 mesh.

JORR-OLIVER

DORR-OLIVER INCORPORATED
INTERNATIONAL HEADQUARTERS
77 HAVEMEYER LANE
STAMFORD, CONN. 06904

BULLETIN NO. D8

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VIBRATING SCREENS

Terms and Definitions

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VIBRATING SCREENS | Terms and Definitions

Amplitude (See Related Term: Stroke)

The distance from the mean position to the point of maximum displacement. In the case of a vibrating screen with circular motion, amplitude would be the radius of the circle. In the case of straight-line motion or elliptical motion it would be one-half of the total movement or one-half of the major axis of the ellipse; thus ½ *stroke*.

Amplitude Card (See Preferred Term: Stroke Card)

Angle (See Preferred Term: Slope)

Angle of Repose

That angle to the horizontal which a material will assume naturally when in a pile.

Angle of Slide

That angle to the horizontal, at which material will slide on an inclined surface as determined by the nature of the material and kind of surface on which it is supported.

Angle, Valley

That angle to the horizontal formed by the line of intersection of two inclined planes such as the angle formed by the joint between the two sides of a hopper.

Aperture

Opening in screening surface.
Also known as clear opening.

Arch (See Preferred Term: Crown)

Automatic Lubrication

Equipment for injecting lubricant into bearings at a controlled volume and frequency.

Backplate

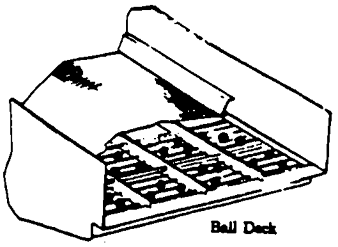
A closure plate across feed end of a screen to prevent spillage.

Baffle Plate

Deflector used to direct the flow of material.

Ball Deck

A special deck which retains balls that strike the underside of the screening surface.



Ball Deck

Base Frame

Stationary structure immediately supporting the vibrating body.

Base Mounted

Denotes vibrating screen supported from structure below, as opposed to overhead suspension.

Bearing

A mechanical vibrator component, usually of the roller type, allowing rotation of the shaft on which it is mounted.

Bearing Closure

A mechanical vibrator component that covers the open end of a bearing housing, with or without provision for a shaft extension.

Bearing Housing

A mechanical vibrator component that holds the outer race of the bearing.

Bearing Seal

A mechanical vibrator component between the rotating and stationary elements, which retains lubricant and excludes foreign matter. Examples are: labyrinth and contact seals.

Bed Depth (See Preferred Term: Depth of Bed)

Blank Plate Section

A form of carrying pan applied like a screen section.

Blinding (See Related Term: Coating and Plugging)

A reduction of open area in a screening surface caused by coating or plugging.

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Body (See Preferred Term: Vibrating Body)

Body-bound Bolt
A finished bolt fitted in a hole machined to close tolerances, thereby denying movement between the bolt and hole.

Bone-dry
Material having no surface moisture.

Bottom Plate (See Preferred Term: Carrying Pan)

Brace Frame (Brace Strut)
Sideplate spacing structural assembly, used in place of support frame.

Bridging (See Preferred Term: Coating)

Buffer Strip
Resilient member, usually rubber, covering the support bars.

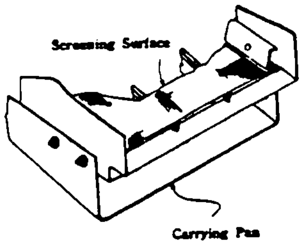
Cable (See Preferred Term: Wire Rope)

Camber (See Preferred Term: Crown)

Capacity
The maximum feed rate that a screen can handle, at a given efficiency.

Carriage Bolt (See Preferred Term: Tension Bolt)

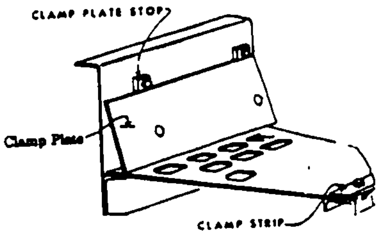
Carrying Pan
A collecting surface located below a screen deck receiving and conveying the thru product from the screening surface. Also known as collecting pan.



Circle Throw
Motion of a vibrating screen which vibrates in a vertical, substantially circular pattern.
Also known as circular stroke.

Circulating Load (See Preferred Term: Recirculating Load)

Clamp Plate
A member located above the screening surface at the sideplate, which holds down the edge of the screen surface, and forms a seal to the sideplate.



Clamp Plate Stop
A small block or bar attached to the inside of the sideplate to limit upward movement of a clamp plate.

Clamp Strip
Any member above the screening surface holding it down to the support frame.

Classification
The process of approximate grouping of material by density or size through the mechanical use of a fluid (air or liquid) medium.

Clear Opening (See Preferred Term: Aperture and/or Space Cloth)

Clogging (See Preferred Term: Plugging)

Close Sizing
The process where the limiting and retaining screen surfaces are nearly the same.

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VIBRATING SCREENS | Terms and Definitions

Cloth (See Preferred Term: Woven Wire Screen Cloth)

Coating (See Related Term: Blinding)

A condition where undersize particles cement over the apertures of the screening surface by virtue of stickiness (generally resulting from moisture content).

Collecting Pan (See Preferred Term: Carrying Pan)

Consistency

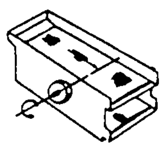
The ratio of dry solids content to the total solid-liquid mixture, expressed in percent on a weight basis, unless specifically stated by volume.

Contamination

The oversize or undersize material (or both), present in a product. Usually expressed as a *percent* of the product.

Conveying Speed (See Preferred Term: Rate of Travel)

Counterflow



Counterflow

Rotation of vibrater shaft such that the top of the shaft is rotating towards the feed end of the machine, or against the flow of the material.

Counterweight

A rotating off-center weight.

Counterweight Shaft (See Related Term: Eccentric Shaft)

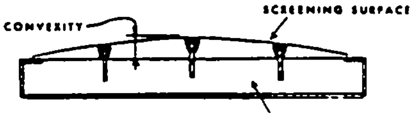
A vibrator component, which has a portion between journal sections with center of mass eccentric to the journals.

Critical Speed (See Related Term: Resonance)

Condition at which the imposed frequency of vibration approximates the natural frequency of the mass-spring system. Usually applied in circumstances where the effects produced are undesirable.

Crown

The convexity of a screen deck, or the difference in elevation between high and low points.



Crown

Dam

An obstruction to the flow of material, mounted on the screening surface.

Damping or Dampening

The reduction of vibration by external means.

Deck

A vibrating screen component consisting of a support frame, screening surface, and accessories.

Deck Preparation (See Preferred Term: Screening Surface)

Degradation

The broken material caused by handling or weathering.

Depth of Bed

Thickness of the layer of material traversing a screen surface.

Desliming

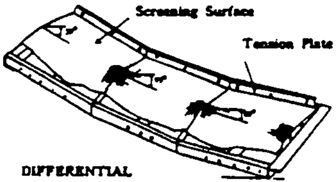
Removal of extremely fine particles from a wet material by passing it over a screening surface.

Dewatering

Removal of free water or surface moisture.

Differential Angle Deck

A screen deck in which successive screening surfaces of the same deck are at varying angles.



DIFFERENTIAL
ANGLE DECK

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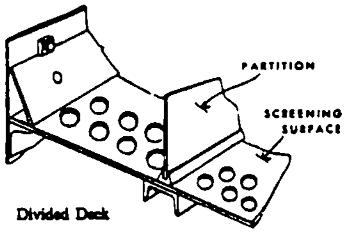
Discharge Spout or Lip

Extension at the discharge end of the screen deck. It may be vibrating or stationary.

Divided Deck

A deck having a screening surface longitudinally divided by partition(s).



Divided Deck

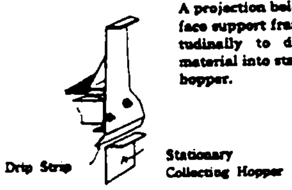
Double Crimped

A term applied to woven wire screen cloth, when the wires in both directions are corrugated.

Draw Plate (See Preferred Term: Tension Plate)

Drip Angle or Strip (See Related Term: Wiper Strip)

A projection below the screen surface support frame running longitudinally to direct liquid and material into stationary collecting hopper.



DRIP STRIP

Drive

All the immediate elements used to provide motive power to the screen, such as V-belts, sheaves, motor, and motor base.

Drive Gear

A gear which propels another gear.

Driven Gear

A gear which is propelled by another gear.

Drive Guard

The enclosure for the power-transmission elements between the screen and the immediate power source.

Dry Screening

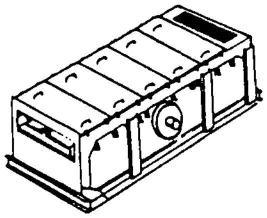
Separation of material without the addition of a liquid vehicle.

Dust Enclosure

Any type of encasement around a vibrating screen for the purpose of controlling dust.

Dust Enclosure—Open Sided

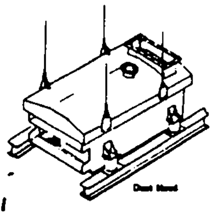
A stationary enclosure with seals extending to the vibrating frame to allow free access to the sideplates for cloth tensioning, with or without air intake or exhaust.



Dust Enclosure - Open Sided

Dust Hood

A stationary cover over the top deck, with provision for dust exhaust.



Dust Hood

Dust Seal

A dust restraining member between a stationary enclosure and vibrating frame.

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Eccentric

An assembly mounted on an off-center portion of a shaft, and used to convert rotary motion to reciprocating motion.

Eccentric Shaft (See Related Term: Counterweight Shaft)

A vibrator component, which has journal sections turned on eccentric centers, or on which eccentric hub(s) or sleeve(s) is (are) mounted.

Eccentricity

The fixed dimension from center obtained from machining a shaft off-center.

Edge Preparation

The fabrication (i.e., hooks, flanges, binders) on the edges of a screen section, which accepts the tension member.

Effective Screening Area, or Net Effective Area

Portion of Screen Deck available for material separation.

Efficiency

The degree of accuracy at which a screen performs a given particle size separation. Specifically: the percent of the undersize in the feed, that actually passes thru the screening surface or,

$$\text{Efficiency}^* = \frac{\text{\% of feed which actually passes through}}{\text{\% undersize in feed (should pass through)}}$$

***Efficiency of undersize recovery**

Not to be confused with contamination (see definition)

See also Appendix A

Effluent

The liquid passing through a screening surface

Electrically Heated Screening Surface

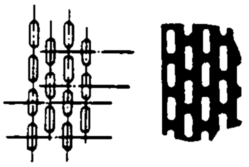
A screening surface which is heated by virtue of the surface itself acting as electrical resistance.

Electro-Magnetic

Denotes a machine or vibrator which has motion created by an electromagnet.

End Stagger (See Related Term: Side Stagger)

A term used to describe a perforated configuration of elongated apertures where the short axes of the apertures fall in line on every row, but the long axes of only every other row fall in line, i.e., "staggered" when looking into the end of the aperture.



End Stagger

End Tension

Tensioning of a screening surface parallel to the material flow.

Exciter

A term used for the vibrater on a machine which operates on the resonant principle.

Feed

The material presented to a screen for processing.

Feeder

A conveying device by which the rate of delivery of material may be controlled.

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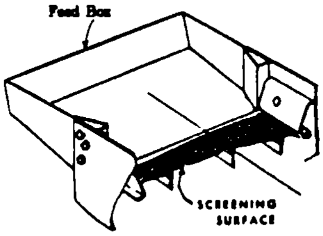
Feed Box

A feed end extension of the vibrating frame which accepts the feed.



Feed Plate (See Preferred Term: Feed Box)

Fill Wire (See Preferred Term: Shoot Wire)

Filler Ring

A mechanical vibrator component inserted in bearing housing, restricting lateral movement of bearing race.

Fines

Material having particle size substantially smaller than a specified aperture. Sometimes used synonomously with undersize, but not recommended.

Fines Hopper

A receptacle located below the screen deck, and receiving the thrus. May be vibrating or stationary.

Fixed Screen (See Preferred Term: Stationary Sieve)

Float (Product)

The lightest weight material fraction from a density separation.

Float (Bearing)

The amount of lateral movement provided for expansion between two parts; viz., bearing outer race in its housing.

Flooding

Feeding screen beyond its capacity.

Floor Mounted (See Preferred Term: Base Mounted)

Floor Stand (See Preferred Term: Pedestal)

Flow Rotation (See Preferred Term: Withflow)

Flowsheet

A schematic drawing showing the various operations of a process.

Fly Wheel (See Preferred Term: Counterweight)

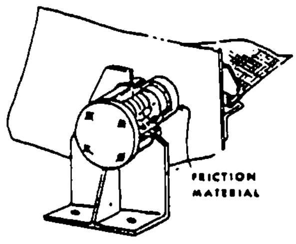
Four Bearing (See Preferred Term: Positive Stroke)

Frequency (See Related Term: Speed)

The number of times an event (viz., complete cycle of motion) repeats itself per unit of time.

Friction Check

A motion dampener of the friction brake type which minimizes stroke build-up during start and stop, and may also laterally stabilize a screen during operation.



Friction Check

Front Plate

A closure plate across discharge end of a screen, below the screening surface.

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G

The acceleration of gravity (32.2 ft/sec^2). Accelerations are usually expressed as multiples of one gravity (viz., 1G, 2G, 3.6G).

Grizzly

A heavy duty screening surface consisting of a series of spaced bar, rail, or pipe members running in the direction of material flow, may be either stationary or vibrating.

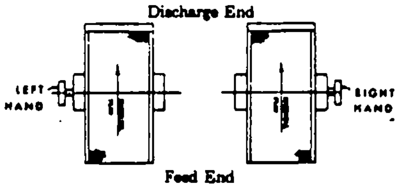
Gyrating Screen (See Preferred Term: Vibrating Screen)

Half-Size

Material having particle size smaller at least in one dimension than one half of a specified aperture.

Hand

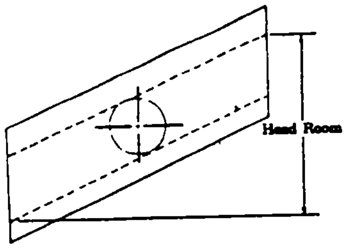
A designation of right or left used to indicate a specific side of a vibrating screen. It is determined when facing in direction of material flow, as it moves *away* from the viewer.



Head (See Preferred Term: Vibrator)

Headroom

Technically, the difference in elevation between the 'working-points' of the feed end of the top deck screening surface and the discharge end of the bottom deck screening surface. Not to be confused with over-all height or vertical clearance.



Heated Deck (See Preferred Term: Electrically Heated Screening Surface)

High Speed

A very relative term referring to the operating frequency of a screen. Used to indicate rpm or cpm generally in excess of 3000.

Holddown Bar (See Preferred Term: Clamp Strip)

Hook Bar

A type of tension member which engages a downturned edge of a screen section.

Hook Bolt

A type of tension member which engages the edge wire of a screen section.

Hook Strip (See Preferred Term: Edge Preparation)

Horizontal Screen

A type of vibrating screen having motion that is substantially straight-line in a vertical plane inclined in the direction of material flow.

Housing (See Preferred Term: Dust Enclosure)

Inclined Screen

A type of vibrating screen with circle throw motion.

Influent

The liquid flowing to a screening surface.

Inherent Moisture

Liquid, usually water, held within the particle.

Inertia Weight (See Preferred Term: Wire Rope Stabilizer)

J-bolt

A fastening device which engages a support bar and holds down the screening surface.

Journal

That portion of a shaft on which a bearing is mounted.

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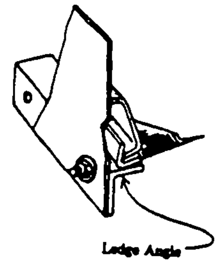
Ledge Angle

Structural member attached to the sideplates that acts as a support for the screening surface.



Left Hand (See Related Term: Hand)

Limiting Screening Surface (Limiting Screen)

The medium determining the largest size particle of a product, thus the medium through which a product has passed.

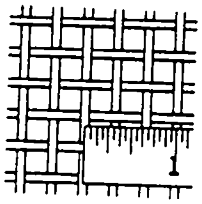
Live Frame (See Preferred Term: Vibrating Frame)

Longitudinal Bar (See Preferred Term: Support Bar)

Marginal Particles (See Preferred Term: Near-Size)

Mesh

Number of openings (and fraction thereof) per linear inch, counting from the center of a wire.



Measuring Mesh

Middling (product)

The intermediate-weight material fraction(s) from a density separation.

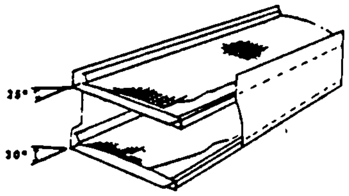
Motor Base

The immediate device on which the motor is mounted, usually providing for belt takeup adjustment. Includes such types as slide rail, pivoted, and spring loaded.

Multiple-Slope Deck (See Preferred Term: Differential Angle Deck)

Multiple-Slope Deck Screen

A screen with decks at different angles.



Multiple-Slope Deck Screen

Near-Size

That material very nearly the size of the aperture, generally considered as plus or minus 25% of the aperture.

Near-Size Overs

That portion of the near-size material larger than the aperture.

Near-Size Thrus

That portion of the near-size material smaller than the aperture.

Oil Flinger

A rotating component of an oil-lubricated vibrator used to distribute the oil.

Oil Mist Lubrication

A continuous automatic, non-recirculative lubrication system using compressed air to mist oil.

Open Area, or Percent Open Area

Ratio of the area of the apertures to the total area of the screening surface.

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Oscillating
Used to denote linear motion, generally in the larger (½" to 2") stroke, and slower (100-400 rpm) speed range.

Overs (Product)
The actual material that passes over a screen surface, including contamination.

Oversize
Material having particle size larger at least in one dimension than a specified aperture.

Pedestal
Support Member(s) for a base mounted screen.

Percent Solids
Commonly specified *by weight* but may be specified *by volume.*

Perforated Plate
A type of screening surface, with various shape openings used for the purpose of separating material.

Plugging (Screen Surface)—See Related Term: Blinding
The wedging or jamming of openings in a screen medium by particles, preventing passage of undersize material.

Plugging (Motor)
The electrical "braking" of a motor to minimise time screen runs thru resonance during stopping.

Positive Stroke
Refers to any vibrating unit having a vibrator with substantially fixed out-board bearings, and with stroke determined by eccentricity of the shaft.

Profile Wire (See Related Term: Deck Preparation)
A type of screening surface using wires of various shapes in cross sections, running substantially parallel to each other.

Rate of Travel
The speed of material over the screening surface usually expressed in feet per minute.

Reciprocating
Usually applied to machines with substantially linear motion in the plane of its main frame. The stroke is normally in the range of 1" to 4", and speeds of 30 to 200 rpm.

Recirculating Load
Material that is rejected (oversize or undersize) in a screening operation, sent to process machinery for further treatment and then returned (recirculated) to the original screen.

Rectangular Opening (Screen Cloth)
When referring to woven-wire screen cloth, having elongated openings defined by single or multiple cross or shoot wires.

Recycle (See Preferred Term: Recirculating Load)

Rejects
A general term applied to unwanted material, either oversize or undersize.

Repulping
The addition of liquid usually at trough locations along the deck, to reslurry the feed.

Resonance
The frequency at which any mass-spring system will vibrate naturally (natural frequency).

Resonant Screen
A form of horizontal screen which uses the principle of resonance to produce its motion.

Retention Time
The time any given particle of material is actually on the screen surface.

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Shoot-Wire

Wires running across the width of the cloth, as woven. Also known as fill, filler, shute, weft or woof wires.

***Side Stagger** (See Related Term: End Stagger)*

A term used to describe a perforated configuration of elongated apertures where the long axes of the apertures fall in line on every row, but the short axes of only every other row fall in line; i.e., "staggered" when looking into the *side* of the aperture.

Side Tension

Tensioning of a screening surface across the direction of material flow.

Sideplate

Structural component of vibrating frame to which vibrator and decks are attached.

***Sieve** (See Preferred Term: Testing Sieve)*

Sieve Analysis

A statement by particle size and percentages of the amount of material in various particle size groupings.

***Sieve Bend** (See Related Term: Stationary Sieve)*

Stationary, profile wire surface usually having a curved portion.

Sieve Ratio

The ratio of the aperture of a given testing sieve, to the aperture of the next finer testing sieve, in a given sieve scale.

Sieve Scale

A list of apertures of successively smaller screening surfaces, used in a multiple-step sizing operation.

Sieve Series

A standardized sieve scale.

Sifter

A screen with rotary motion substantially in the plane of the screening surface.

***Sink** (Product)*

The heaviest weight material fraction from a density separation.

***Size Consist** (See Preferred Term: Sieve Analysis)*

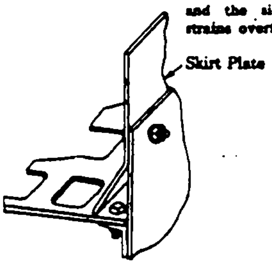
***Sizing** (See Preferred Terms: Screening and Separation)*

Skid Bars

Longitudinal members attached to top of screening surface.

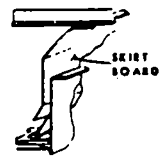
Skirt Plate

A member attached to the sideplate above the screening surface, which seals the gap between it and the sideplate; and/or restrains overflow of material.



***Skirtboard** (Stationary)*

A member supported independent of the vibrating body, above the top deck, inside the sideplates, to restrain overflow of material.



Skirtboard (Stationary)

Slope

The angle with the horizontal made by the first or top deck screen section(s). Must be specified as *uphill* or *downhill.*

***Slotted Opening** (Screen Cloth)— See Preferred Term: Rectangular Opening*

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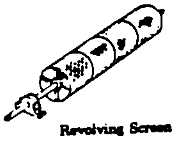
Revolving Screen



Revolving Screen

A cylinder mounted on rollers, on a shaft with the screen surface forming the circumference. Also known as trommel, scrubber, or barrel screen.

***Right Hand** (See Related Term: **Hand**)*

Rinsing

Washing of fines or foreign material from the feed.

Rod Deck

A type of screening surface usually made up of round rods, arranged parallel to each other, replaceable individually or in small sections.

Round Hole Equivalent

The dimensions of any shaped opening in a screening surface, that will make essentially the same separation as specified round hole.

Scalper

A vibrating screen used for scalping at any aperture.

Scalping

Strictly the removing of a small amount of oversize from a feed which is predominantly fines. Typically, the removal of oversize from a feed with approximately a maximum of 5% oversize, and a minimum of 50% half-size.

***Screen** (See Related Terms: **Shaker, Sifter, and Vibrating Screen**)*

A machine with screening surface(s) used to classify materials by size.

***Screen Box** (See Preferred Term: **Vibrating Frame**)*

***Screen Cloth** (See Preferred Term: **Woven Wire Screen Cloth**)*

Screen Section

A finished piece of screening surface complete with edge or other preparation.

Screening

A mechanical process which accomplished a division of particles on the basis of size, and their acceptance or rejection by a screening surface.

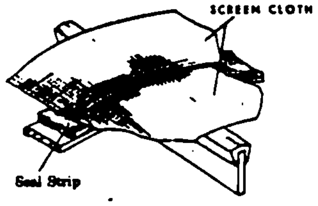
Screening Surface

The medium containing the apertures for passage of the undersize material.

***Seal** (See Preferred Terms: **Bearing Seal and Dust Seal**)*

Seal Strip

Transverse or longitudinal member, or sealing medium, at joint and/or end of screen sections.



Selvage

A finished edge of woven wire screen cloth produced in the weaving process of the finer meshes.

Separation

The specific process of particles being presented to apertures and being *rejected* if larger than the opening or *passed* through if smaller.

Shaft Casing

Structural component protecting the vibrator shaft(s) and normally extending between the sideplates.

Shaker

A screen with reciprocating motion.

Shear Mounts

Resilient supports, usually rubber, where the flexible member is loaded in shear.

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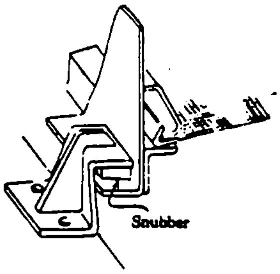
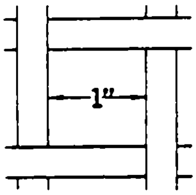
Snubber
A flexible device that restricts motion.



Space Cloth
Denotes class of screen cloth, the specification for which is determined by measuring the opening, rather than "mesh".



Measuring Opening

Speed
The frequency at which a vibrating screen operates, usually expressed in rpm or cpm.

***Split Deck** (See Preferred Term: **Divided Deck**)*

***Square Mesh** (See Preferred Term: **Mesh**)*

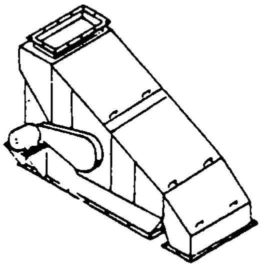
***Square Opening** (See Preferred Term: **Space Cloth**)*

***Stabilizer** (See Preferred Term: **Friction Check**)*

Stapling
The obstruction of the apertures by long fibrous material looped over the wires or bars of the screening surface.

Start-Stop Bounce
A condition of increased motion (stroke) when passing thru resonance.

Stationary Enclosure
A type of dust enclosure supported independent of the vibrating frame.



Stationary Enclosure

Stationary Sieve
A screening surface usually employing a profile wire, commonly sloped.

Step Deck
A series of screening surfaces, each located in progessively lower parallel planes along the vibrating screen.

***Step Washing Plates** (See Preferred Term: **Trough**)*

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Straightline Motion (See Preferred Term: Horizontal Screen)

Stratification

The process or phenomena whereby the larger size particles rise to the top of a bed of material being shaken or vibrated, while the smaller size particles sift through the voids and find their way to the bottom of the bed.

Stroke (See Related Term: Amplitude)

The distance between the extremities of transverse; viz., the diameter of a circular motion.

Also used synonymous with "motion"; viz., straight-line "stroke".

Stroke Card (See Related Term: Stroke Indicator)

Card on which the motion of the screen is inscribed. Accomplished by attaching card to sideplate and holding a stationary marker against the card.

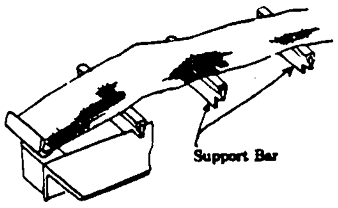
Stroke Indicator (See Related Term: Stroke Card)

A device attached to the sideplate from which stroke can be read directly.

Support Bar

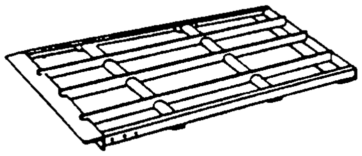
Members of the screening surface support frame, that form the crown of the deck.

Also known as bar rail, bridge rail, bucker-up bar, or longitudinal bar.



Support Frame

A vibrating frame component, which supports the screening surface.



Support Frame

Support Tray

An easily removable unitised form of support frame.

Surface Moisture

The film of liquid (usually water) adhering to the exposed surface of the particle.

Suspended Screen

A screen hung from overhead.

Sympathetic Vibration

The motion of a member or structure in resonance with a transmitted vibration.

Tailing

Waste product in ore classification.

Tension Bolt (See Related Term: Wedge Bolt Tensioner)

Threaded bolt used with tension member.

Tension Member

A general term for any of a number of devices which engage the edge of the screen surface, and pull it taut over the support frame.

Tension Plate (Board)

Type of tension member that is located above the screening surface and closes the gap between the edge of the screen surface and the sideplate.

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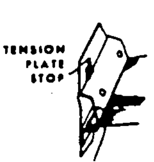
Tension Plate Stop



Tension Plate

A small block or bar attached to the inside of the sideplate to limit upward movement of a tension plate.

***Tension Skirtboard** (See Preferred Term: **Tension Plate**)*

Tensioning

The stretching of the screening surface within the vibrating rame.

Testing Sieve

A cylindrical or traylike container with a screening surface bottom of standardized apertures.

***Throw** (See Preferred Term: **Stroke**)*

***Thrus** (Product)*

The actual material that passes thru a screening surface, ncluding contamination.

***Thrust Ring** (See Preferred Term: **Filler Ring**)*

Total Moisture

The sum of inherent and surface moisture.

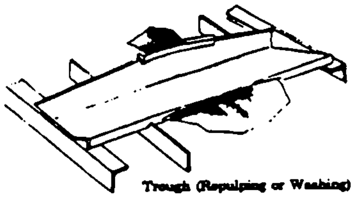
***Totally Enclosed** (See Preferred Term: **Dust Enclosure**)*

Tray Deck

An easily removable unitized form of deck.

***Trough** (Repulping or Washing Trough)*

A transverse, solid deck portion between screen sections.



Trough (Repulping or Washing)

***Tube Housing** (See Preferred Term: **Shaft Casing**)*

Two Bearing

Refers to any vibrating unit that employs a single shaft with two bearings.

***U-bolt** (See Related Term: **J-bolt**)*

A fastening device which engages a support bar and holds down the screening surface.

***Unbalanced Pulley** (Screen)*

Type of screen on which the stroke is determined solely by the counterweight.

Undersize

Material having particle size smaller at least in one dimension than a specified aperture.

***Veil Plate** (See Preferred Term: **Blank Plate Section**)*

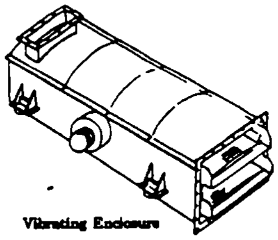
***Vibrating** (See Preferred Term: **Vibrating Screen**)*

Vibrating Body

Complete vibrating screen other than stationary items.

Vibrating Enclosure

A type of dust enclosure where hoods, covers, or pans are attached to the vibrating frame as an integral part.



Vibrating Enclosure

EXHIBIT "14"-Terms and Definitions of the Vibrating Screen Manufacturers Association 1967

VIBRATING SCREENS | Terms and Definitions

Vibrating Frame
Complete structural portion of a vibrating unit primarily composed of sideplates and cross members. Does not include vibrator, shaft casing, mounting or suspension parts, and non-structural appurtenances.

Vibrating Screen
A screen with motion in a vertical plane which operates generally above 600 rpm at less than 1" stroke.

Vibrator (See Related Term: Exciter)
The stroke inducing mechanism of any vibrating equipment, mechanical or electro-magnetic. Sometimes incorrectly used to designate vibrating screen.

Vibrator Tube (See Preferred Term: Shaft Casing)

Warp Wire
Wires running parallel to length of cloth, as woven.

Wedge Bolt Tensioner
A slotted bolt and wedge assembly used with tension member.

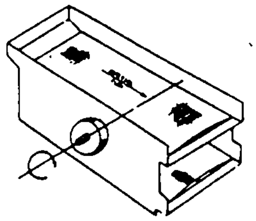
Wet Screening
Separation of material with the addition of vehicles such as water.

Wiper Strip (See Related Term: Drip Angle or Strip)
A member below the screening surface in contact with it and/or longitudinal supports, to deflect liquid.

Wire Rope Stabilizer
Weights that are attached to wire rope suspension cable to prevent their whipping. Also known as inertia weight.

Wire Rope Suspended (See Preferred Term: Suspended Screen)

Withflow
Rotation of the vibrator shaft such that the top of shaft is rotating toward the discharge end of the machine.



Withflow

Woven Wire Screen Cloth
A type of screening surface, woven in square, rectangular or slotted openings.

EXHIBIT "14"-Terms and Definitions
Of the Vibrating Screen
Manufacturers Association 1967

APPENDIX "A"

Efficiency of Screening

Since "the job" in every case is to get Undersize in the Feed to pass through the Screening Surface, the definition in the text of this book is a basic one, following the concept of all Efficiency definitions; viz., work or result out divided by work or potential in.

However, many other definitions for, and concepts of, Screening Efficiency have been offered and are in various use. Some involve the concept of "difficult" particles or "Near-Size."

One other generally recognized formula is for:

$$\text{Efficiency of } \underline{\textit{Removal}} = \frac{\text{\% of feed (or amount) which is oversize}}{\text{\% of feed (or amount) which actually passes over}}$$

……………………………………

Returning to the definition used in this text:

Efficiency is the percent of the Undersize in the Feed, that actually passes thru the Screening Surface, or

$$\text{Efficiency (of Undersize Recovery)} = \frac{\text{\% of feed (or amount) which actually passes thru}}{\text{\% of feed (or amount) which is undersize (should pass thru)}}$$

There is a very convenient way to determine the Efficiency of a Screen Separation "in the field." Obtain simultaneous samples of the Feed and Overs product, run a size breakdown or sieve analysis of these two samples, and apply the following formula:

$$\text{Efficiency} = \frac{a-b}{a\,(100-b)}$$

Where a = percent Undersize in Feed
b = percent Undersize in Overs Product

<u>EXHIBIT</u> "14"-Terms and Definitions
Of the Vibrating Screen
Manufacturers Association 1967

IN THE SUPREME COURT

OF WESTERN AUSTRALIA

No. 2313 of 1982

EXHIBIT "15(1)"-Affidavit of Robin John Batterham dated 25.5.83

IN THE MATTER of an Agreement between LANGLEY GEORGE HANCOCK, ERNEST ARCHIBALD MAYNARD WRIGHT, WRIGHT PROSPECTING PTY. LTD., HANCOCK PROSPECTING PTY. LTD, two other companies and HAMERSLEY IRON PTY. LIMITED

BETWEEN:

HAMERSLEY IRON PTY. LIMITED	Plaintiff
AND	
LANGLEY GEORGE HANCOCK	First Defendant
ERNEST ARCHIBALD MAYNARD WRIGHT	Second Defendant
HANCOCK PROSPECTING PTY. LTD.	Third Defendant
WRIGHT PROSPECTING PTY. LTD.	Fourth Defendant
L.S.P. PTY. LTD.	Fifth Defendant
THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED	Sixth Defendant

AFFIDAVIT

I, ROBIN JOHN BATTERHAM of 9 Moorna Court, Mt. Eliza in the State of Victoria, Research Scientist, make oath and say as follows:

1. (a) I hold the degrees of Bachelor of Chemical Engineering (1965) and Doctor of Philosphy in Chemical Engineering (1968) from the University of Melbourne. I am a Chartered Engineer (United Kingdom), a Member of the Institution of Chemical Engineers (United Kingdom), a Member of the Iron and Steel Society of the American Institute of Mining, Metallurgical and Petroleum Engineers and a Fellow of the Australian Institute of Instrumentation and Control.

   (b) After completing my doctorate I spent two years with the Corporate Research Laboratories of Imperial Chemical Industries Limited in the United Kingdom on a post-doctoral fellowship awarded by the

William G. Brody Jr.
25/5/1983

Robin John Batterham

Commonwealth Scientific and Industrial Research Organisation ("the CSIRO"). I then took up duties with the CSIRO, spending a period on projects involving the Australian sugar industry before becoming involved, from 1973, in the work I am now doing in the mineral area.

(c) Since 1980 I have been Section Leader of the Chemical Engineering Section of the CSIRO's Mineral Engineering Division and in 1982 I was made a Senior Principal Research Officer. The Chemical Engineering Section concentrates on the optimisation and control of large-scale mineral processing in Australia and works in close collaboration with both producers and processors. Much of the work involves the development of mathematical models and the validation of their predictions against operating plants. Both development and validation of the models necessitate the detailed and accurate measurement of operating plants and a thorough knowledge of their practical working. The measurements are made in the field at the operational sites and have required lengthy visits by me to iron ore processing facilities, including those at Tom Price, Paraburdoo and Dampier, Whyalla, Port Latta/Savage River in Tasmania and Newcastle as well as to non-ferrous concentration and smelting plants at Cockle Creek and Mt. Isa. In the course of my duties in the Mineral Engineering Division I have also visited numerous iron ore crushing, screening, concentrating and processing operations in Sweden, the Netherlands, France, Belgium, the United Kingdom, Canada and the United States of America. In addition I have visited research centres concerned with crushing, screening and processing in most of those countries.

(d) I am the author of approximately 50 technical reports and a greater number of technical papers covering the various projects in which my Section has been involved. I have presented seminars at various university departments of mineral processing or metallurgy including those at Imperial College (London), the University of British Columbia, the University of California, Pennsylvania State University, the University of Utah and various Australian universities. In 1982, I co-chaired an international conference on Comminution in Hawaii.

William G Moody Jr.

25/5/1983

Robin John Batterham

(e) I was a consultant to Mitchell Cotts/Minenco, the Joint Venturer responsible for the design of the Tom Price concentrator and one of the projects referred to in sub-paragraph (c) above involved me in a detailed study of the screening and ore handling operations at all of the Plaintiff's operational sites, including the running of screening tests over a long period on the sites and research into the effect of moisture on screening. I have inspected the Tom Price concentrator in detail on a number of occasions, my most recent visit being in March, 1983.

2. I have been asked to advise the Plaintiff in relation to these proceedings and I have read, and ask leave to refer to, the Affidavit of Colin Roy Langridge sworn on 2nd September, 1982, the Affidavits of Niles Earl Grosvenor and Peter Forbes Booth both sworn on 27th October, 1982, the Affidavit of Alban Jude Lynch sworn on 22nd May, 1983, the Affidavit of Arthur Noel Pritchard sworn on 24th May, 1983 and the Affidavit of Douglas Frederick Tompsitt sworn on 24th May, 1983 all filed herein. I have also examined the exhibits to each of those Affidavits, including the Agreement which is "Exhibit CRL 1" and the photographs which are "Exhibit DFT 1".

3. I say without hesitation that in my opinion Dr. Lynch is the leading authority in Australia on mineral processes. His expertise in this area is well recognised both internationally and within the Australian mining and mineral processing industry. His reputation is based on his close familiarity with the operations of Australian mineral processors and his understanding of the significance and objectives of each stage in mineral dressing operations. Mr. Pritchard is also well known to me and is recognised throughout the Australian mining and mineral processing industry as having long experience in and a thorough and extensive practical knowledge of screening processes and their application.

4. I agree with the conclusions expressed by Dr. Lynch in paragraph 9 of his Affidavit and with the reasons he gives for those conclusions and, except that I have no direct knowledge of the industry before 1973, with paragraphs 5, 6, 7 and 8 of Mr. Pritchard's Affidavit. Like them I am not aware of any iron ore processing plant where a wet process was in use in 1962 or is in use now solely as an adjunct to crushing and screening, without some further process in view.

William G Broady J.P.
25/5/1983

Robin John Batterham

EXHIBIT "15(1)"-Affidavit of Robin John Batterham dated 25.5.83

In the context of iron ore processing it is artificial to exclude crushing and screening from other forms of beneficiation because they are integral parts of the process of progressive beneficiation of the ore on its journey from mine to smelter. A distinction may however be drawn by reference to the fact that crushing and screening are beneficiation processes concerned with size as opposed to beneficiation processes concerned with some other characteristic such as the removal of impurities. If water is added a form of beneficiation results which is quite independent of upgrading on the basis of size. The chemical upgrading is also of a different order. I adopt what Dr. Lynch says in paragraphs 6 and 7 of his Affidavit and would simply add the following by way of amplification.

6. Particles of ore can be held together by van der Waals and electrostatic forces and capillary pressure. Van der Waals force is the natural attraction that exists between molecules at close proximity. Electrostatic force operates by virtue of the attraction between molecules with positive charges and molecules with negative charges. Clay molecules tend to hold and transmit such charges very efficiently. Capillary pressure exists where there is moisture in the ore. The moisture forms a bridge between small particles and, because of the surface tension it creates, binds them into larger agglomerate pieces. Molecules of clay tend to absorb moisture very readily. There is a good deal of the clayey material referred to by Mr. Langridge in the concentrator feed at Tom Price.

7. Van der Waals and electrostatic forces are effective in making particles stick only as long as stronger forces do not drive them apart. Water at high pressure will often drive such particles apart when mere agitation on a screen would not be enough to do so. In a process like that in the Tom Price washing and screening house the water not only drives apart relatively small particles held to larger particles but also relatively small particles held to each other by those two forces. Because bonding by capillary pressure depends on the presence of limited moisture, the capillary effect can also be destroyed by flooding the bonded particles with enough water to break the surface tension between the particles. Each of these three forces and their elimination are dependent on surface properties rather than the sizes of the particles on which they operate.

William G Moody Jr.
25/5/1983

Robin John Batterham

EXHIBIT "15(1)"-Affidavit of Robin John Batterham dated 25.5.83

8. Because heavy media concentration is a wet process the very first wetting of the ore must, in my opinion, be seen as the start of that process. In order for the ore to be treated in the drums, cyclones and WHIMS water must be added sufficiently prior to those units to allow the release of the fine impurities and fine recoverable particles which would otherwise harm the heavy separation medium and impede its later recovery for future use.

9. If a size separation of the ore between 30 and 80mm from the -30mm fraction were the only objective of the top primary screen, water would be unnecessary because the screen apertures for a cut at that size would not become choked by the smaller particles. They would simply fall through as undersize. "Exhibit NEG 1" shows that more than half the water used in the washing and screening plant is introduced prior to or on the top screen deck. The purpose and effect of doing so can only be to maximise the time during which all the ore is subjected to water so that a thorough break-down of water-active shales takes place and a separation and cleaning of the fine particles is effected.

10. The photographs in "Exhibit DFT 1" referred to in paragraph 2 above, were taken by Mr. Tompsitt at my request and show the progressive effect of water on the concentrator feed.

SWORN by the said ROBIN)
JOHN BATTERHAM at Oakleigh)
in the State of Victoria)
this 25th day of May)
1983.)

Robin John Batterham.

Before me:

William G Moody J.P.
A Justice of the Peace

SUPREME COURT
WA
WESTERN AUSTRALIA

Filed on behalf of the Plaintiff.

EXHIBIT "15(1)"-Affidavit of Robin John Batterham dated 25.5.83

EXHIBIT "15(2)"-Ammended paragraph 5
to the Affidavit of Robin John
Batterham dated 25.5.83

DR. R.J. BATTERHAM'S AFFIDAVIT

5. In the context of iron ore processing it is artificial to exclude crushing and screening from other forms of beneficiation because they are integral parts of the process of progressive beneficiation of the ore on its journey from mine to smelter. A distinction may however be drawn by reference to the fact that crushing and screening are beneficiation processes concerned with size as opposed to beneficiation processes concerned with some other characteristic such as the removal of impurities. If water is added, an element of beneficiation results which is in addition to and causally distinct from the upgrading resulting from screening according to size alone. This will reflect in chemical analyses differing in the two cases. I adopt what Dr. Lynch says in paragraphs 6 and 7 of his Affidavit and would simply add the following by way of amplification.

EXHIBIT "15(2)"-Ammended paragraph 5
to the Affidavit of Robin John Batterham
dated 25.5.83

EXHIBIT "16(1)" - Diagram showing simulation of scrubbing and screening of Tom Price Concentrator

SIMULATION OF HI SCRUBBING, SCREENING

14C #1

c	calculated
W	weight
F	% Fe

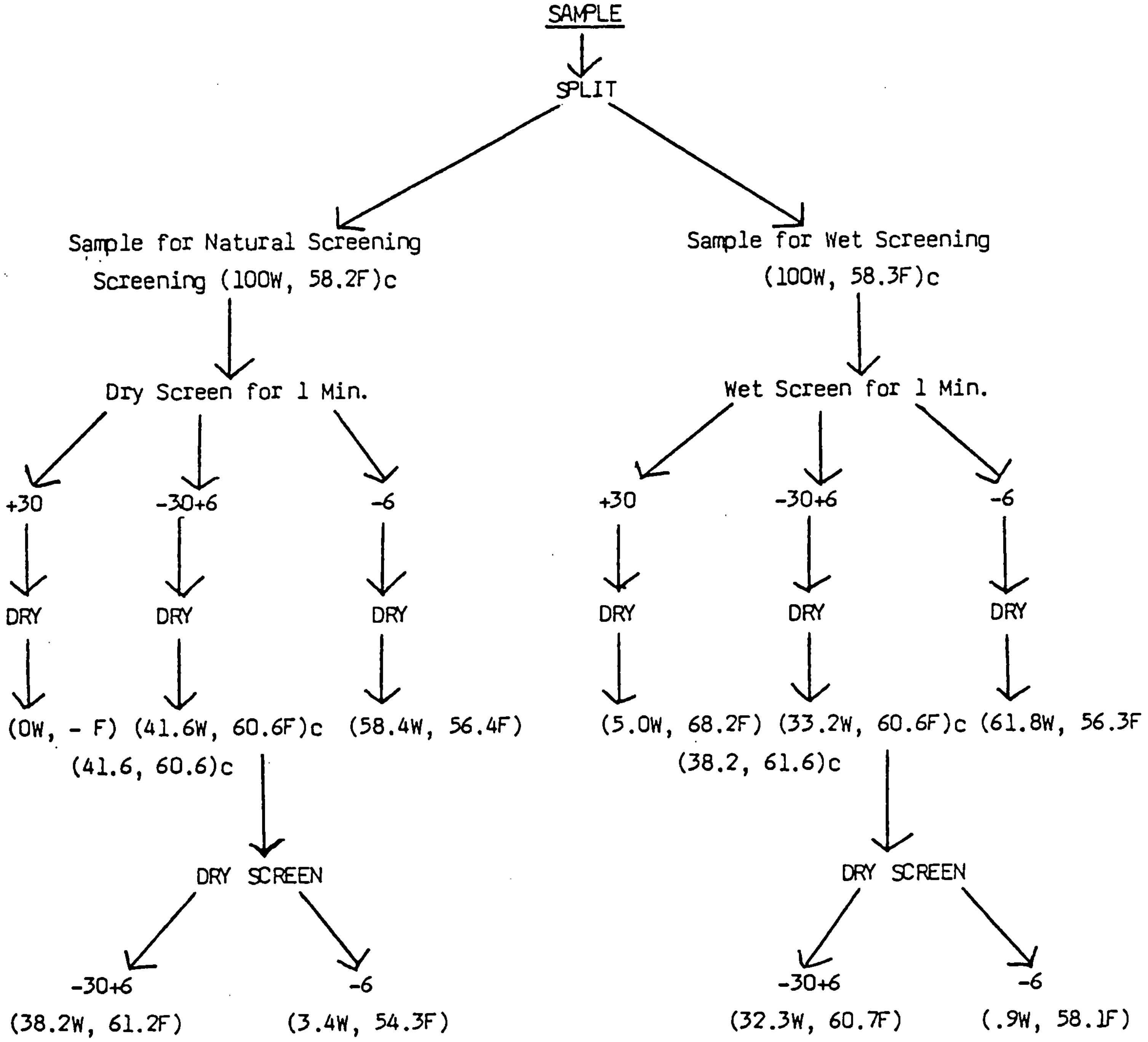


EXHIBIT "16(1)" - Diagram showing simulation of scrubbing and screening of Tom Price Concentrator

EXHIBIT "16(2)" - Diagram showing simulation of scrubbing and screening of Tom Price Concentrator

SIMULATION OF HI SCRUBBING, SCREENING

14C #2

c	calculated
W	weight
F	% Fe

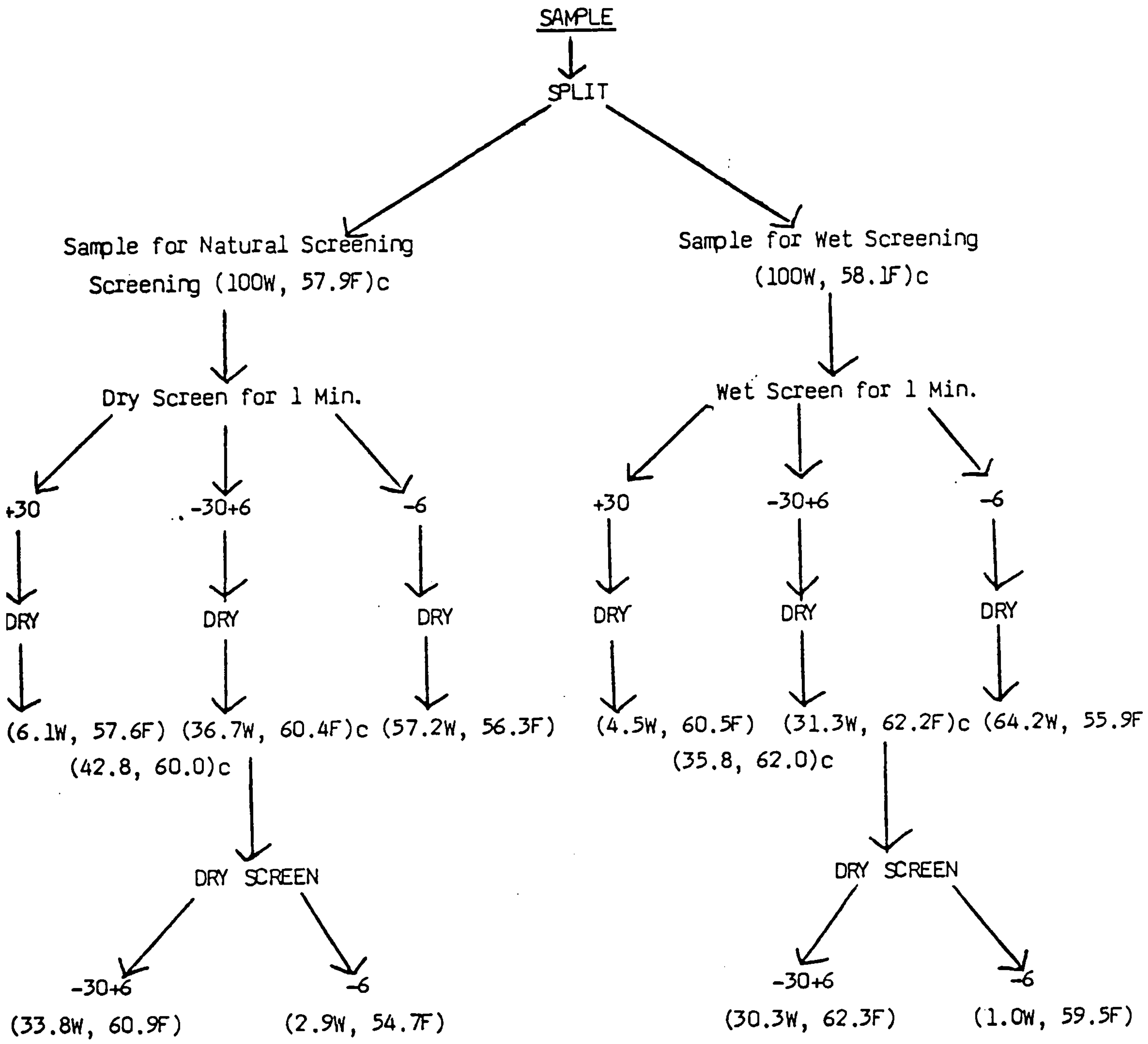


EXHIBIT "16(2)" - Diagram showing simulation of scrubbing and screening of Tom Price Concentrator

EXHIBIT "16(3)" - Diagram showing simulation of scrubbing and screening of Tom Price Concentrator

SIMULATION OF HI SCRUBBING, SCREENING

50C #1

c	calculated
W	weight
F	% Fe

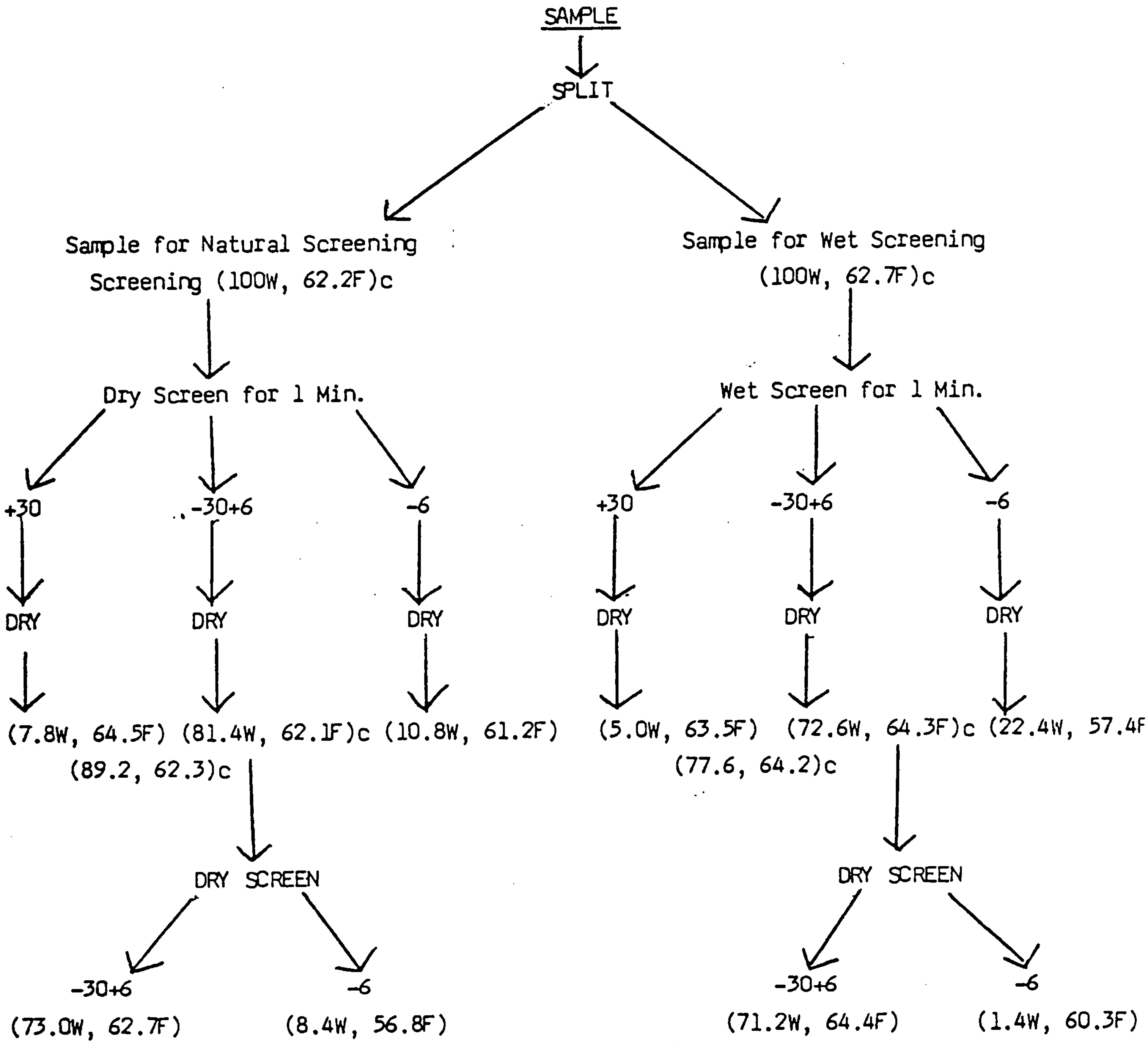


EXHIBIT "16(3)" - Diagram showing simulation of scrubbing and screening of Tom Price Concentrator

EXHIBIT "17" - Copy Chapter 9 from "Mineral Processing" by Pryor

CHAPTER 9

INDUSTRIAL SIZING AND SORTING

Preliminary

Sizing, as performed on screens, grades material according to the minimum cross-section presented during the time of passage across the meshes of the screen cloth. The regularity of the industrial product is dimensional, and takes no account of differences between the weights of the particles in a given grade. "Sorting", or as it is more usually called classification, discriminates between the behaviour of particles in a fluid and grades them according to their surface, volume, and density. Since ores contain particles of varying densities, this is not a sizing operation. The fluid mostly used is water, though high-density salt solutions are employed for special purposes. Material required in a dry state may be sorted by floating it in air currents of controlled strength. Screening is only used for comparatively coarse material, as the rate of treating large quantities of ore becomes slower when fine-meshed screens are used. Wet screening is practised commercially down to 65 mesh, but industrial dry screening is rarely carried below 20 mesh. Classification can be used from coarse-sand sizes down to well below 200 mesh. Fine particles (say —20 mesh) must have fluid mobility if they are to be sorted, and these conditions cannot be contrived with a long-ranged dry feed subjected to screening.

Ore may be screened for any of the following purposes:

(*a*) To retain oversize in a given section or circuit, and thus prevent it from being fed to a machine not suitable for dealing with it.
(*b*) To remove undersize from the feed to a crushing machine set to treat bigger lumps.
(*c*) To grade rock into specified sizes.
(*d*) To present a correctly sized feed to a concentrating process.

Classification is used to:

(*e*) Separate ore into relatively coarse and fine fractions by exploiting differences in settling rates.
(*f*) Split a long-ranged feed into fractions settling equally.
(*g*) Close grinding mill circuits so that no particles escape from them into the concentrating section of the plant until they have been reduced to the desired sizes.
(*h*) Remove or segregate slimes.
(*i*) Regulate size-range fed to a process.

EXHIBIT "17" - Copy Chapter 9 from "Mineral Processing" by Pryor

Action on the Screen

The purpose in screening is to hold as oversize all particles too large in their minimum cross-section to pass through the apertures, and to let all smaller ones drop through as undersize. The separated products are then sent to their next processing point by independent routes. The behaviour of a particle upon the screen depends chiefly on the relationships listed in Table 13. Consider first the ratio of its cross-section to that of the meshes (*a*). A relatively small particle has no difficulty in falling through, but the nearer it approaches "retaining mesh", the more difficulty it has in hitting an unoccupied mesh centrally with a suitable presentation. Shape plays a part, the fairly equidimensional particle having a better chance than the acicular or tabular one, unless the screens have been chosen to assist such shapes.

TABLE 13

(*a*) Ratio between cross-section of particle and of mesh.
(*b*) Percentage of screen area open.
(*c*) Angle of incidence of feed.
(*d*) Efficiency of spread of feed over screen area.
(*e*) Kinetic energy of particle approaching screen opening.
(*f*) Moisture of ore feed.
(*g*) Stickiness of particle and of aggregated particles.
(*h*) Pressure of particles riding above those next the screen cloth.
(*i*) "Blinding" of screen apertures.
(*j*) Corrosion of screen material.
(*k*) Electrostatic "bunching".
(*l*) Shape of particle.
(*m*) Percentage of "near-mesh" particles in the feed.
(*n*) Rate of feed, thickness of layer, tautness of screen.
(*o*) Shape of screen apertures.
(*p*) Motion imparted to particle by screen vibration.

Square-meshed cloth does its best work when set horizontal, but the shaking movement imparted to it must then have a forward transporting component. Oblong meshes are often used for feed which is moist or clayey, and for needle-like particles. If the feed tends to "blind" the cloth, the long axis of the rectangle is set in the direction of flow. Square mesh is usual with tabular material. The percentage of screen area open (*b*) depends on weave, diameter of screen wires, and shape of aperture. For a given mesh various ratios of opening are available. (*c*) is concerned with the mode of arrival on the screen. Ideally, a particle would fall with its minimum cross-section normal to the aperture and at negligible velocity. In practice, it competes with a crowd of other particles of random shape and size, falling along various trajectories. Hence item (*d*) is most important, since the wider the entering feed is spread, the easier will it be for a particle to find unobstructed passage to the screening surface. Since this is so (*e*) should be low. A particle flying nearly horizontally toward the screen is most likely to hit the layer of feed with its broadest dimension and to slide down on top, with no early chance of burrowing its way down. (*f*) and (*g*) vary with climate

EXHIBIT "17" - Copy Chapter 9 from "Mineral Processing" by Pryor

and working conditions and to some extent can be compensated by using slightly larger screens in the monsoon season. (*h*) can aid the work where the screen cloth has little or no vertical motion, but when the action is designed to "dance" the feed along, it exerts what is on the whole an undesirable damping pressure. (*i*) arises partly from near-mesh material and is worst in closed-circuit work (*m*) where the return particles tend to be close to "release-mesh" and so to be retained. Such material prevents the passage of true undersize and cuts down the capacity of the screen, so that it is usually found desirable to provide more generously for screening in closed circuit than in grading open-circuit ore, or to use a screen aperture greater than the set of the crusher. (*j*) introduces roughness along the wires, and greatly increases the proneness to "blind" and to resist clearance of the blinded apertures. Corrosive pitting is lessened when the ore can be neutralised with lime, or if a resistant alloy is used for the screen wires. (*n*) affects the resistance the upper particles must overcome in penetrating the feed bed, while the tautness of the cloth decides how vigorously and widely the shaking and tossing action of the agitating mechanism is transmitted to this bed. Finally (*p*) can be modified on some mechanical screens to allow any variation in the vibratory orbit of a free particle from counter-current to concurrent. With electrically vibrated screens the upward movement of the cloth, as it vibrates normal to the direction of flow, can be terminated by abrupt arrest, thus "unblinding" the cloth at each stroke. This action is not possible on mechanically shaken screens, which can, however, be assisted in keeping open by the slapping action of rubber cords stretched below.

Types of Separating Surface

The grizzly (Fig. 17) was described in Chapter 3. Robustly built screens (Fig. 70) are also available. The one shown can handle up to 1000 tons of large rock hourly with far less loss of head than would be possible on the static surface of a fixed grizzly. The machine must stand up to rough treatment and the impact of heavy rock.

Punched screen is used for many purposes (Fig. 71). A variety of shapes is manufactured, circular openings being recommended for coarse work and slotted ones for fine.

Woven-wire cloth is widely used in the range between ¼" and 200 mesh. Various shapes of aperture, crimps and weaves are available (Fig. 72). Steel, stainless steel, monel metal, copper, and bronze are the chief metals from which cloths are made. For delicate work at fine meshes, dry material is sometimes sieved through silk or nylon. For special purposes very fine square-meshed screens are made by electro-forming instead of weaving. They are sold in 100' lengths three feet wide, with hole diameters in the range 25μ down to $2\frac{1}{2}\mu$. The screen surface is nickel, on a copper base. Conventionally woven materials of construction include mild steel, brass, phosphor-bronze, copper, copper-nickel, nickel-chrome, austenitic stainless steel, galvanised and tinned mild steel. In milling, steel screen wire should not be used to treat acidic and corrosive ores, unless it is first protected by being

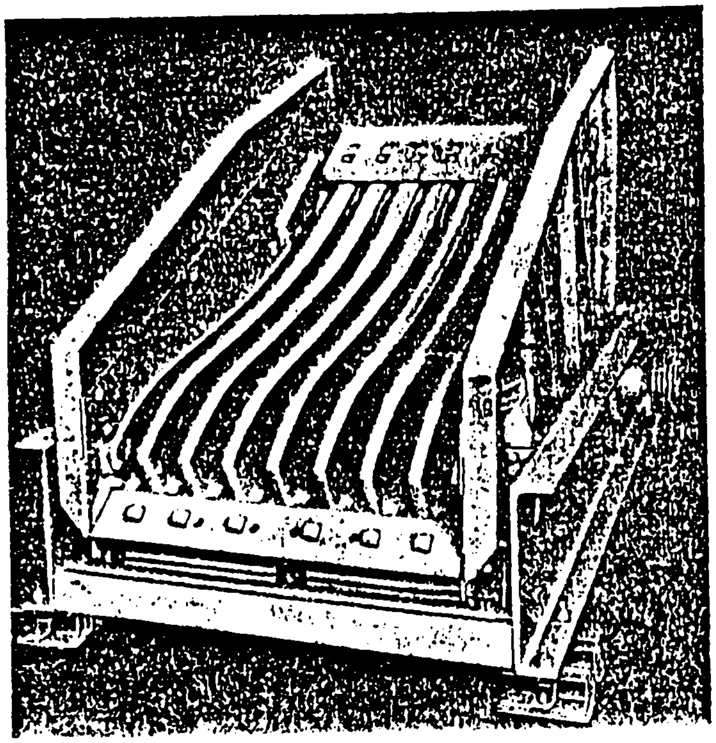
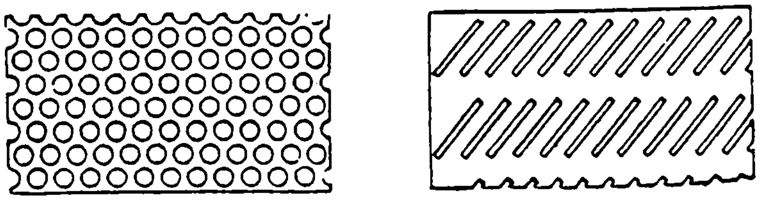
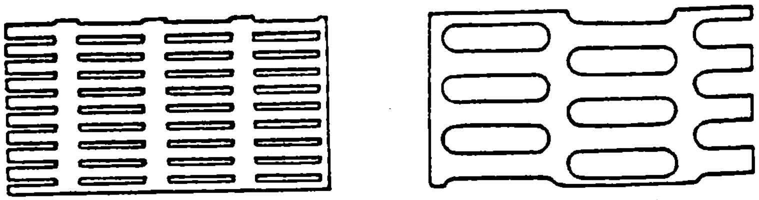


Fig. 70. Vibrating Bar Grizzly (Nordberg Manufacturing Co.)



Round holes

Diagonal slots



Slots

Rounded ends

Fig. 71. Types of openings. Punched Screens

SUPREME COURT WESTERN AUSTRALIA

EXHIBIT "17" - Copy Chapter 9 from "Mineral Processing" by Pryor

given a suitable plastic coating. Where corrosion is not serious, high carbon steel is suitable, being strong and hard wearing. Maximum capacity of screens with oblong apertures is obtained by using them with the long side of the mesh set across the flow.

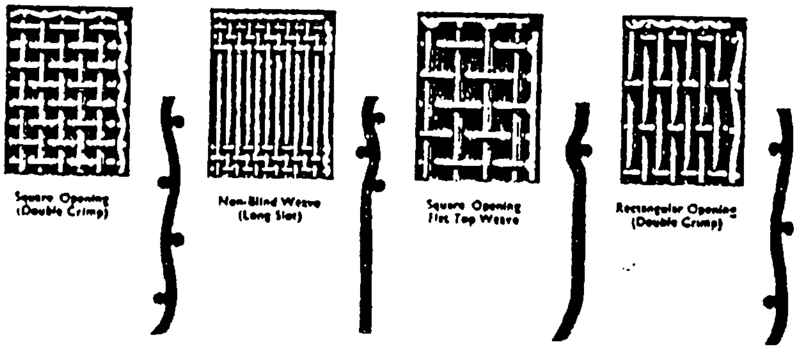
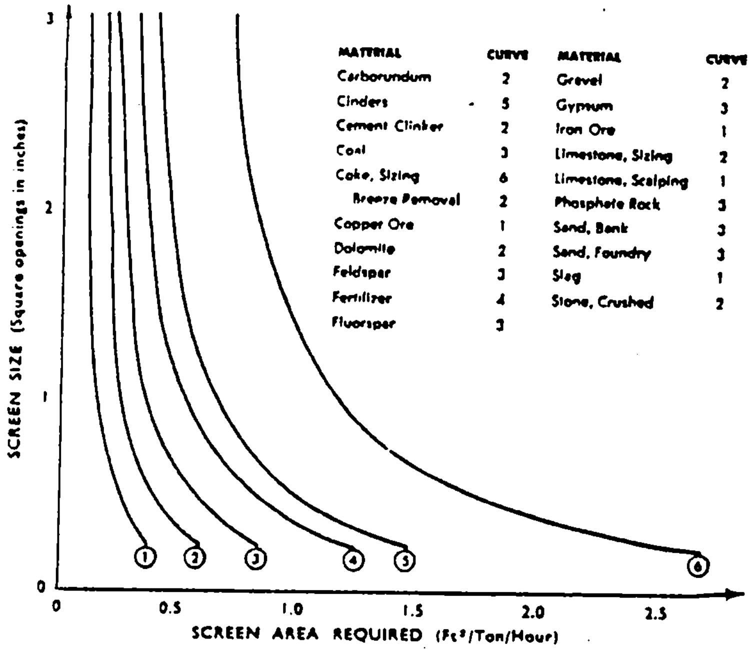


Fig. 72. Types of Woven Screens



MATERIAL	CURVE	MATERIAL	CURVE
Carborundum	2	Gravel	2
Cinders	5	Gypsum	3
Cement Clinker	2	Iron Ore	1
Coal	3	Limestone, Sizing	2
Coke, Sizing	6	Limestone, Scalping	1
Breeze Removal	2	Phosphate Rock	3
Copper Ore	1	Sand, Bank	3
Dolomite	2	Sand, Foundry	3
Feldspar	3	Slag	1
Fertilizer	4	Stone, Crushed	2
Fluorspar	3		

Fig. 73. Screen Capacity. (Denver Equipment Co.)

In Table 14 the recommended wire diameters for screens with openings from ⅛" to 4" are given, together with percentage open area. The screen area required for a given feed tonnage can be estimated by use of the graph in Fig. 73. The appropriate curve is selected and the screen area (sq. ft. per ton per hour) is read for the required linear opening (ordinate) or square-meshed screen-cloth. The area figure (abscissae) is then multiplied by the tons per hour to be screened. The curves are representative where the feed contains less than 65% of oversize and where about 50% of the undersize is about half the screen-size opening.

TABLE 14

STANDARD COARSE SCREEN SPECIFICATIONS

Recommended by the Division of Simplified Practices, U.S. Department of Commerce, for screening of mineral aggregates

Opening	*Wire Diameters*							
	Medium Light		*Medium*		*Medium Heavy*		*Heavy*	
	Wire Diameter Inch	*% Open Area*	*Wire Diameter Inch*	*% Open Area*	*Wire Diameter Inch*	*% Open Area*	*Wire Diameter Inch*	*% Open Area*
4"	·500	79·0	·625	74·8	·750	70·9	1·000	64·0
3½"	·4375	79·0	·500	76·6	·625	72·0	·750	67·8
3"	·4375	76·2	·500	73·5	·625	68·5	·750	64·0
2¾"	·375	77·4	·4375	74·4	·500	71·6	·625	66·4
2½"	·375	75·6	·4375	72·4	·500	69·4	·625	64·0
2¼"	·375	73·4	·4375	70·1	·500	66·9	·625	61·2
2"	·3125	74·8	·375	70·9	·4375	67·3	·500	64·0
1¾"	·3125	71·9	·375	67·8	·4375	64·0	·500	60·5
1½"	·250	73·4	·3125	68·5	·375	64·0	·4375	59·9
1⅜"	·250	71·5	·3125	66·5	·375	61·6	·4375	57·5
1¼"	·250	69·4	·3125	64·0	·375	59·2	·4375	54·8
1⅛"	·225	69·6	·250	67·0	·3125	61·0	·375	55·7
1"	·225	66·6	·250	64·0	·3125	58·0	·375	52·9
⅞"	·207	65·3	·225	63·3	·250	60·5	·3125	54·3
¾"	·192	63·4	·207	61·4	·250	56·3	·3125	49·8
⅝"	·177	60·7	·192	58·5	·225	54·0	·250	51·0
½"	·162	57·1	·177	54·5	·192	52·2	·207	49·8
7/16"	·148	55·8	·162	53·2	·177	50·7	·192	48·3
⅜"	·135	54·1	·148	51·4	·162	48·7	·177	46·1
5/16"	·120	52·2	·135	48·8	·148	46·0	·162	43·4
¼"	·105	49·6	·120	45·6	·135	42·2	·148	39·4
3/16"	·080	49·1	·092	45·1	·120	37·2	·135	33·8
⅛"	·054	48·7	·072	40·2	·092	33·4	·105	29·5

Heavy wire recommended for trommels.
Medium heavy for high speed vibrating and shaking screens.
Medium light and medium for other vibrating screens.

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In addition to the foregoing, rod-deck screens are used for coarse work. The rods are sprung into place and can be changed individually. Wedge-wire screening is employed for some purposes. It is strong and can be made with small apertures. The blunt sides of the wedge strips which form the separating surface are upward, so that material passing falls clear without "blinding". Many other wire shapes are obtainable.

When a long range of sizes is being fed to a comparatively weak or light screen, a robust coarse screen should be mounted above it to form a double-decked system in which the heavier pieces do not reach the second deck. A delicate screen can be supported by a coarser backing screen beneath. The apertures in punched-plate screening may be round, square, rectangular, or oblong with rounded ends, the last-named being less prone to blind than holes completely circular. These screens are made of steel, steel alloy, brass, monel, copper, or bronze. If openings are disposed in an equilateral triangular pattern, the maximum ratio of opening to total surface is obtained. The stouter the plate, the closer can be the openings and the longer the service life. Against this must be set the fact that the thicker the plate the greater the proneness to blind, and the higher the initial cost. This blinding with increased thickness is still more noticeable with woven wire.

The selected aperture depends on the working requirement, while constructional strength depends on the nature, size, and loading of the feed. The ratio of aperture to screen area is not, therefore, a function of the mesh in commercial screens. For instance, an 8-mesh screen woven from thin wire can have 24% more screening area than a 6-mesh weave in thick wire. Hence, the opening required dominates specification as regards size of product, but the total amount of screen capacity available at any point in the flow-sheet depends partly upon the thickness of weave of the selected mesh. Screens undergo such rough treatment that their working life may be measable in hours in extreme cases. Flow of ore must be interrupted while a broken cloth is being replaced. This consideration affects the choice as regards robustness of wires.

Screening Machinery

Since separation must be made of all sorts of feeds, varying in condition from the completely dry to the sticky, clayey, or "porridgy", each ore presents its own screening problems. Capacity, efficiency, mesh size, and wear rate are relative to the specific ore and should dictate the choice of appliance. The flat grizzly is used to retain large oversize which might cause trouble if allowed to continue to the next point in the flow line. It is sturdy enough to act as an anvil if such oversize is to be sledged down by hand, or can operate in conjunction with any required breaking arrangement.

The inclined grizzly is sloped between 25° and 39° if it delivers its oversize to a crushing machine, the gradient being chosen to allow sliding control by means of hand or chain feeders. If the oversize is to run to the crusher free of control, a slope well in excess of 35° from the horizontal is usual. For dry quartz 45° should suffice, while sticky or moist rock might need 50° or

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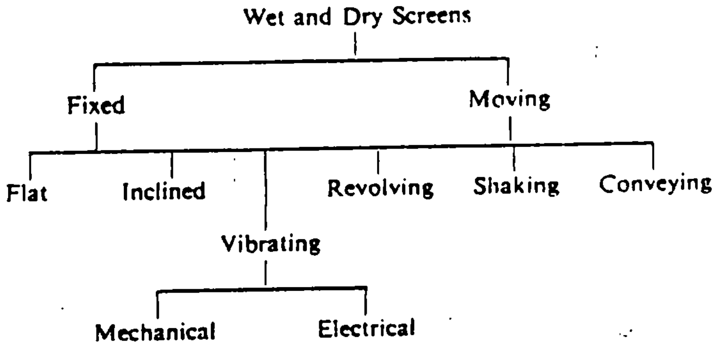
more. Grizzlys are simple and strong, but are wasteful of headroom. The general types of separating device are presented schematically thus:



The roll grizzly consists of a series of grooved rollers driven by sprocket and chain unidirectionally in a supporting frame, the speed increasing from entry end to discharge roll. The undersize drops between the grooves while oversize moves flatly along. With this arrangement loss of head is minimised, but power is needed for the roll drive.

Grizzlys can be vibrated mechanically, electrically, or by the impact of falling rock. They may also be shaken, or alternate bars may be moved by eccentrics. They can be used as sorting tables or to control the rate of feed. The mechanically vibrated bar grizzly illustrated in Fig. 70 is designed to separate ore at 1½" bar spacing or more, and handles up to 1000 tons/hour.

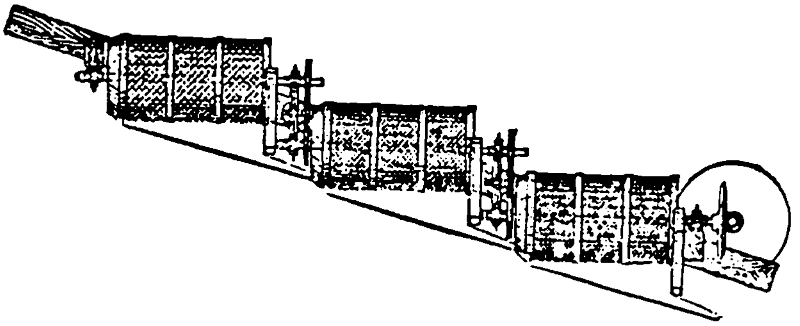


Fig. 74. Trommels in Series

The curved bars tend to tumble the feed, and the vibrating action, powered by a 7½ h.p. motor, is effective on wet and sticky ore. The jar-bar feeder grizzly is illustrated in Chapter 3.

One of the oldest screening devices is the trommel, which can be used wet or dry. Its usual form is cylindrical, with the screening plates forming the side walls, and a downward slope from feed to discharge end. Trommels may be arranged in series (Fig. 74), with the coarsest discharge at the start.

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in order to remove heavy oversize at the earliest point and by means of the most robust screenplates. When "washing trommels" are used, the feed is picked up by internal lifters made of angle-iron, and is sprayed. The water runs out with the undersize and slime. A variation of the series of diminishing-mesh trommels is the compound trommel with concentric screens, the coarsest inside, and separate discharge launders for the products. The disadvantage of this arrangement is that failure of a screen is hard to observe and difficult to deal with quickly. Other variations include the polygonally-sided trommel which gives positive lifting action to its contents and permits a complete flat screen to be replaced as a unit. To overcome the problem of providing a skewed bevel drive to sloping trommels, the conical trommel, set horizontally and flaring down from feed to discharge, has had some use. Trommels are chiefly used as sizers in gravel plants and stone-breaking work, and on tin and gold dredges where they remove boulders and clay from the gravels brought up by the buckets. In tin dredging a serious source of loss of cassiterite is that due to embedding of the mineral particles in nodules of clay, either because the richest alluvial ore lies directly on clay bottom in the deposit, or through the jumbling of gravel and clay together during digging and discharge from the dredge buckets. "Disintegrating trommels" have been used, with cutting blades rotating inside the revolving cylinder. These meet and slice up clay lump, so that the trapped cassiterite is released and can run through as undersize. Trommels are simple, vibration-free, cheap, strong, and economical of head loss through a series. Against this must be set the fact that they "blind" easily, have poor capacity and cannot be repaired speedily or changed rapidly to a different mesh. Apart from the uses mentioned above, the vibrating screen has replaced the trommel for most ore-dressing purposes.

Shaking screens are usually worked dry, and chiefly in the sorting of coal. A typical arrangement consists of an oblong box of which the screen forms the bottom. This may be hung by chains or links, or supported from beneath. In the latter case the Ferraris motion may be used. The Ferraris truss carries a loaded deck by means of flexible battens set at a calculated angle. When the deck is pressed forward the battens move through a rising arc, lifting the load and throwing it forward. On release, the deck falls backward to its stop-point, the effect being to toss the ore in the air, or at least to reduce its clinging contact with the screen after the forward stroke has imparted to it kinetic energy in the direction of travel. This loosening aids in the stratification of the ore, and leaves the largest particles on top, where they press upon the smaller ones which are trying to work through the meshes of the screen. The upward tossing motion can aid in unblinding (a little), while the jarring arrest as the deck falls back tends to loosen particles wedged in the meshes. The vibration of shaking screens is a disadvantage, and they are today but little used for hard-rock work.

Travelling-belt screens are typified by the Callow screen. In this, usually made duplex, the screen cloth is bound along the selvedge to rubber strip which forms a retaining lip on each side. Ore pulp is fed on, washed through by sprays, and removed as undersize, while oversize is discharged at the far end. They are little used today.

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Vibrating Screens

These screens dominate modern sizing practice. They handle dry to moist or sticky material as coarse as 10" in ring size, and as fine as 65 mesh. In special cases they can work on dry feed down to far finer sizes. For most mineral-dressing operations, screening stops at the point where the crushing section delivers ore to the fine-ore bins for wet milling (say between ¾" and ¼" size), though an important tonnage is handled by gravity concentrators after screening down to 20 mesh. Once wet milling has begun, sizing usually gives place to sorting in classifiers though wet screening is being increasingly used on sands.

Vibrating screens can work at low slopes and need but little headroom. Though loss of height as material drops through a machine is not an expensive item, it influences plant layout and the choice of appliances and should be minimised. Other important advantages of vibrating screens are accessibility, easy visual control, crisp transmission of the input power, and (given good design) avoidance of transmission of vibration to the mill structure.

The vibrating screen has one or more decks, usually plane and kept in sprung tension. The screen forms the floor of a box which is vibrated mechanically or electrically. The electrically vibrated screen (Fig. 75) uses an electro-magnetic device (Fig. 76), usually a solenoid arranged to set up a reciprocating motion. This solenoid is activated by alternating current, and a striking block or anvil may be incorporated in the design. The rising motion is communicated to the screen-cloth through a rod. Lift can be made to terminate with a jarring blow adjusted so as to counteract "blinding" of the meshes. In other variations, the electrically induced vibration may be resisted by adjustable springs, thus modifying the severity with which the screen is vibrated. A slight variation in the frequency of the A.C. supply has a magnified effect on the motion.

If the pushing and pulling of the solenoid acts direct *via* transmitting rods upon the tensioned screen-cloth (and this is the usual arrangement), the ore particles dance normally to the surface unless (as in conveying screens shaken in this manner) the movement is applied at an angle. There are no rotating parts, and but little that calls for maintenance. Metallic dust occasionally gathers around the striking anvil and leads to sparking. It is removed by blowing with compressed air. The screens are mostly used on —½" feed.

The most widely used screens for coarser sizing are mechanically vibrated. The motion impressed upon a particle is not necessarily a simple straight-line one. Anything between this and a circular orbit spinning either counter-current to the feed (giving the particle a tendency to climb back toward the feed end) or concurrent (accelerating its progress toward the discharge end) is in theory feasible. One advertised motion shows a counter-current ellipse at the feed end, a reciprocation normal to the screen at the centre, and a concurrent ellipse toward the discharge. The oncoming feed is thus stated to be checked and searched during stratification, then sent down to an area of screen unusually free from blinding, and finally accelerated off the screen. These variations are produced by balancing the forces producing vibration, the movements of the tensioning springs, the yield of the screen cloth, the

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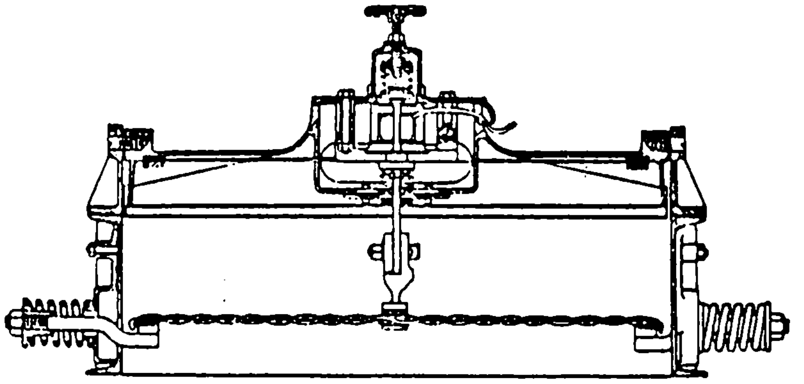

Fig. 75. The Hummer Screen

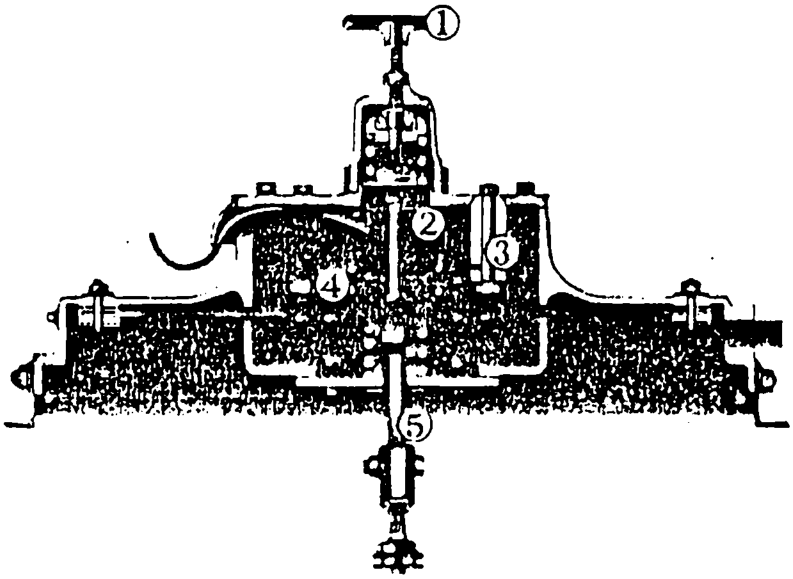

Fig. 76. Cross Section of Hummer V16 Vibrator (International Combustion)

1. Hand wheel for regulating intensity of vibration
2. Coil and magnet
3. Striking block, wearing plate and shims
4. Armature
5. Armature post and bracket

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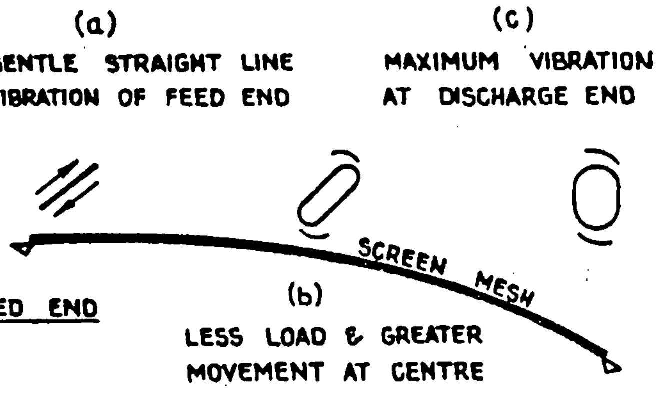

Fig. 77. Compound Particle Orbits on Screen
(Mining Bulletin, King's College, Durham, No. 11)

inertia of the framing, and the weight of the passing load. A motion developed in connexion with the screening of coal is shown in Fig. 77.

There are two main methods of producing vibration. For feed coarser than a limiting size of the order of 1½", eccentric motion is preferred. Below this, and increasingly down toward a retaining mesh of ⅛", the unbalanced pulley is favoured.

Eccentric motion imparts a circular orbit. The typical arrangement con-

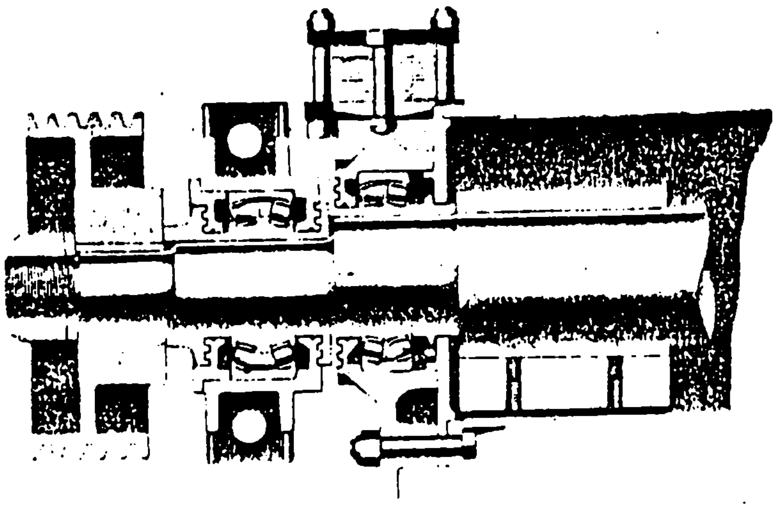

Fig. 78. Floating Eccentric Drive Unit (Nordberg Manufacturing Co.)

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sists of a floating drive unit of which one end is shown in Fig. 78. From left to right are (*a*) the drive unit, (*b*) a concentric bearing which carries a side bar attached to the balance deck (*c*) a follower bearing connected to the screen deck, and (*d*) the main shaft. When the revolving shaft attains its operating speed the total throw of the eccentric (*c*) is divided between the screening and balancing deck in inverse proportion to their weights. Many variations in detail have been developed by the manufacturers, all being designed to lesson the mutual strain between shaft and follower and to avoid transmission of vibration to the mill structure by feeding back such impulses 10 in the form of useful work. Boxes can be tilted, sometimes while running, between horizontal and 30°.

Where an unbalanced weight is revolved, vibration results. This can be

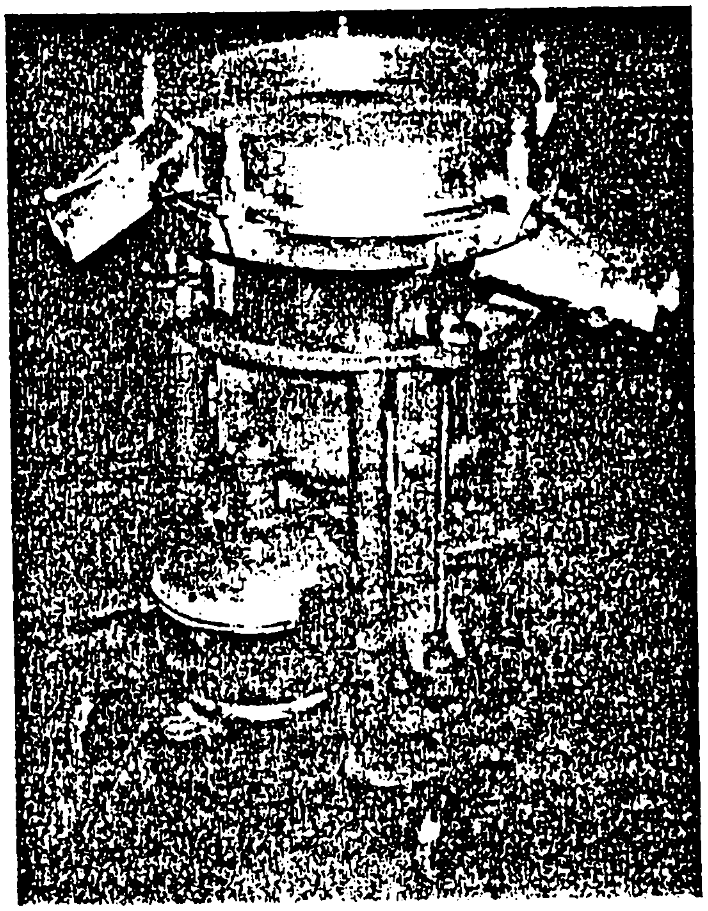

Fig. 79. Russell Screen

made to shake a screen box. In the simplest form an unbalanced rotating shaft is mounted across the screen box. In more developed systems the driving shaft is balanced and spins two sets of unbalanced flywheels. One set is keyed to the shaft while the other set can be locked in any desired relation to the keyed set, thus giving neutralisation or reinforcement of the out-of-balance force generated at each revolution. In a third form of development there are two driving shafts, rotating in opposite directions at the same rate, each carrying unbalanced weights. These weights then pull in the same direction twice per revolution, and oppose each other twice. The screen box is mounted on springs, or in flexible rubber blocks. The Russell screen (Fig. 79) incites a gyratory motion generated by an unbalanced weight.

In dry screening, dust protection of the moving parts is desirable. It should be a simple and speedy matter to change a cloth, to adjust its tension, and to ensure that feed is being evenly spread over the whole area.

The vibrating action can conduce to local flexing and premature fracture of the screen wires. The mode of attachment of the cloth to the holding frame or bars must be designed to minimise this effect, and also to permit rapid change of screen-cloth.

Mine ore is often moist or sticky. One method of reducing the blinding and clogging of the meshes by such feed is to heat the screen wires by gas or electricity. Below about 20 mesh, the rate of efficient dry screening becomes increasingly uneconomic. Classification, which takes over when this happens, has some drawbacks when used on sands much coarser than those in the 65–100 mesh range. Further, sorting action in a classifier does not give size discrimination. There is constant pressure on the industry to extend the practicable range of wet screening.

"Wet" Screening

If the ore can be simultaneously held in suspension and given screening action the adverse effects of specific surface friction are reduced. Several ways of doing this have been worked out, but the difficulty in keeping a pool of hydraulic water where it is wanted while at the same time allowing the undersize to be screened away is considerable. Sprays can be directed on the passing layer of ore with turbulent strength, but the water thus used rapidly drains out, leaving the fairly fine ore in the form of a wet sand or silt in which screening motion is almost *nil*, since the wet particles are clinging tightly to each other. Reciprocation of the screen surface under water in a pool has been tried, but is subject to the difficulty of "dashpot" damping of the vibration, and to the fact that a particle free to move in air has a far greater effective thrust downward than one which is waterborne and colliding with many others.

An approach, which has been claimed as economic in some plants, uses a series of sprays (Fig. 80) to repulp the ore as it passes along the screen. If new water is used, this entails considerable dilution and an ample supply of fresh water, but this repulping water can be clarified and recirculated. A refinement of this method for which good economy in use of water is claimed,

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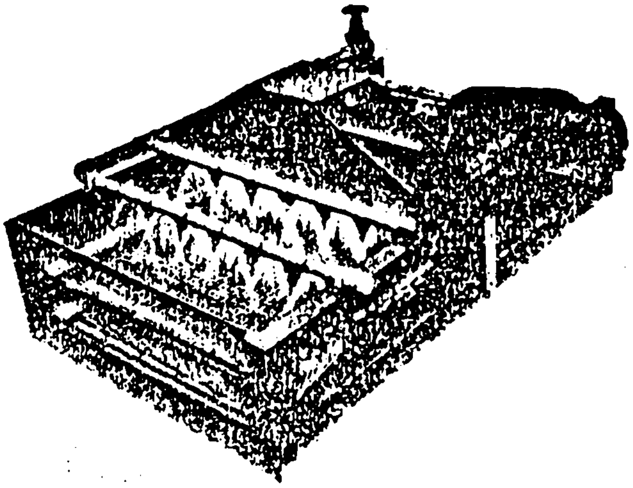

Fig. 80. *Screen with Sprays* (Deister Concentrator Co.)

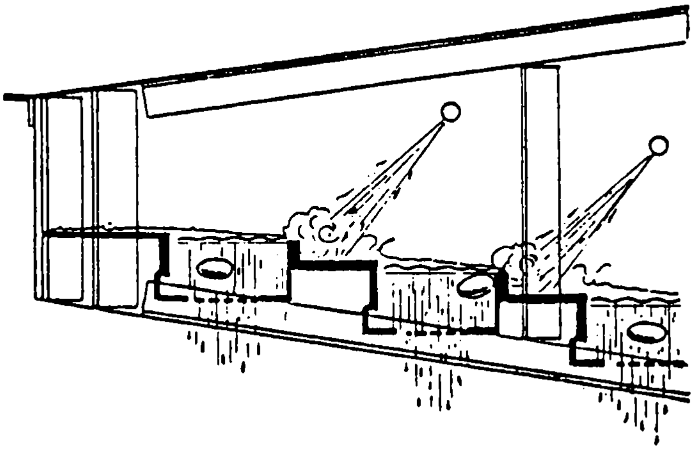

Fig. 81. *Horizontal Wet Screens* (Allis-Chalmers)

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the "pool washing screen" (Fig. 81). The deck is interrupted at intervals by a transverse "pool" into which water is sprayed. The feed arriving from the previous section of screen-cloth is pulped in this pool, and the undersize readily drains through the screen on the next section. This wet screen is made with stepped series of decks, inclined deck, or a pool-interrupted flat deck.

A stationary screen, the Dutch State Mines "Sieve Bend"[1] has gone into considerable industrial use in the past few years. It handles satisfactory volumes in a small mill space and makes good separation down to 100 mesh or finer, with throughput as high as 50 tons per hour. The separating surface is a stationary concave (Fig. 82) formed of wedge-wire bar screen set across the pulp flow. Modified shapes are marketed in which the concaves extend over 60°, 120°, or 300° of arc. In the last of these feed enters vertically from

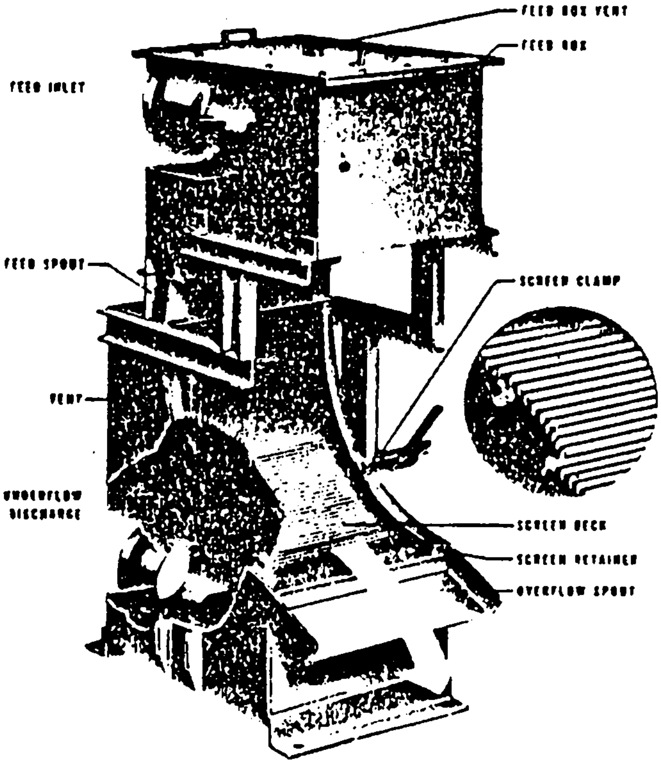

Fig. 82. *Sieve Bend Screen (Dorr-Oliver)* beneath and is either delivered *via* an internal baffle or a flat nozzle, so as to sweep up and round the interior of the partial cylinder formed by the horizontal wedge bars. These are spaced from 50μ to 150μ apart and have a standard length of 63". Construction material is stainless steel and maintenance is light since there are no moving parts. Power cost is limited to the pumping needed to present the pulp at the required height and velocity.

A novel wet-screening method has been developed by Hukki.[2] The experimental arrangement (Fig. 83) consists of a cubic box which receives the feed at one side, a stirring arrangement deep in the box, and inclined vibrating screens through which the undersize overflows above. Baffles in the box direct the flow, and sand oversize is removed below *via* an adjustable discharge valve.

Efficient Operation

The simplest expression for efficiency of screening is the weight of undersize actually obtained as a percentage of the weight of undersize actually in the feed. This expression is not of great practical value, however, since it ignores the effect on efficiency of particles of near-mesh size. Particles just too large to pass the limiting mesh, or so large as only to pass with difficulty, are far more prone to blind the available separating meshes than others in the feed. Obviously, the efficiency of the screen is related to the dwelling time of transient material and to the openings available during its passage, hence this near-mesh material defeats a simple formulation. When the screen is closing a crushing circuit, the tendency is for a near-mesh circulating load to build up, so that a progressive falling-off in screen efficiency and capacity is to be expected as this increases. The criterion of efficiency used by one manufacturer is stated as 100 minus the percentage of true undersize in the rejected oversize, and this is a better practical figure. Efficiency varies between 60% and 80%, and increases with:

(*a*) the percentage of the screen open to passage of undersize;
(*b*) the smoothness and freedom from pitting of the mesh wires;
(*c*) the suitability of the shape of aperture to the average particle shape under treatment;
(*d*) the time taken in transit.

Efficiency is adversely affected by:

(*e*) increasing the rate of feed;
(*f*) increase in percentage of near-mesh grains;
(*g*) thickness of bed which hinders presentation of particles;
(*h*) lack of "liveliness" of the screen cloth in responding to the vibrating impulses;
(*i*) moisture in the feed (this can be serious).

Efficiency can be calculated by means of the two-product formula

$$R = \frac{100c(f-t)}{f(c-t)}, \qquad (9.1)$$

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R is recovery, and f, c, and t are percentage sizes of feed, concentrate tailing (Taggart, *Manual*, 19-191, Eq. 133).

This formula, together with that for ratio of concentration

$$K = \frac{(c-t)}{(f-t)}. \tag{9.2}$$

can also be used to show the relative amounts of sand discharge and overflow. K is the ratio of weight in feed to the weight of concentrate. In this case sand takes the place of the valuable product usually shown.

Square mesh exercises a restraining effect in two dimensions, whereas an oblong mesh gauges the passing particle in one principal dimension. It thus increases screen capacity at the expense of accuracy. The choice of mesh shape must take into account three interrelated criteria—precision of sizing, permissible tolerance of wrong sizes, and effect on overall operating profit. Usually in mineral dressing, optimum liberation is finally regulated at the classifier overflow, and it suffices in the screen-controlled sections if material too large for efficient comminution in the next grinding section is held back at any designated points. In this case, square-mesh accuracy is rarely of vital importance. Rectangular mesh is favoured for acicular particles, and for moist or clayey feed smaller than ¼". Slabby particles are best handled on square mesh. Material prone to blind the meshes should be treated on oblong screens set with the long axis in the direction of flow. If the screen product is to be delivered to mineral jigs the tighter size control possible with square meshed cloth may be found important.

Suitable tensioning of the cloth in its securing frame is needed. The vibrating strokes should be distributed fairly evenly over the whole area, (*a*) to avoid overstress at a point, line or node and (*b*) to ensure adequate tossing of the passing stream of ore.

Good tension of the screen cloth is desirable to give efficient transfer of the vibrating strokes from mechanism, *via* cloth, to load. Backlash and slackness of the assembly are bad for efficiency. The combined effect of vibration speed and amplitude, together with slope of screen, must be such as will keep the material well stirred and running freely. If the amplitude is too great, stratification will be upset and near-mesh particles will not be adequately "ridden" into the meshes. If it is too feeble, the apertures will blind. The moisture of the incoming feed may vary seasonally, in which case several cloths of varied mesh can be kept ready, and changes made in aperture to suit the altered condition of the feed.

Capacity of a section monitored by screening is higher when oversize is not returned for retreatment but is sent to a different crushing system. This is probably due to the lessening of re-circulated material not crisply dealt with by the crusher from which it has already escaped to the screen. In a large mill the cost of an extra crushing stage may be justified, but a small plant would return the oversize in closed circuit for another pass. This arrangement could be aided by the use of a screen rather larger than the set of the crusher so as to keep down the volume of near-mesh circulating load.

The possibility would arise with spring-loaded crushers rather than those having a rigid set.

The area round a dry screen is usually dusty, and may require hooding and an extracting system. The main running cost in screening is for replacement of cloth, subsidiary items being for power, labour, and loss of gravity head through the appliance. Where the screens are set to gauge the size of an important product it may be desirable to take special precaution against delivery of oversize owing to the unnoticed rupture of a screen. This may be done by duplicating the same mesh on a double-decked machine. If the upper cloth ruptures, oversize will commence to come over from the lower one, and this change can be caused to actuate an alarm.

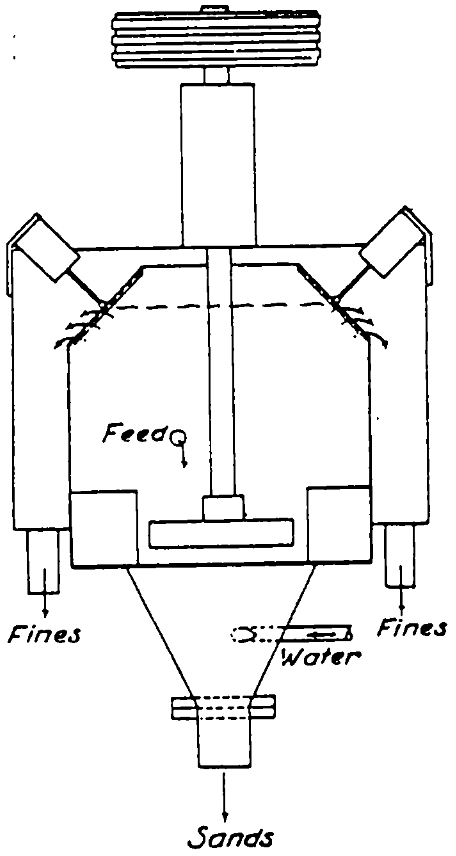

Fig. 83. *The Hukki Screening Cell*

Screens may be classified in terms of the path of a point on the vibrating surface. The five types listed in a Paper by Kuenhold[3] include full or mod-

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med circular throw (vertical or horizontal), and lineal reciprocation (vertical, tilted, or horizontal). In coarse sizing vertical circle motion is most widely used, either from an eccentric drive or an unbalanced shaft. The size of screen used is governed by duty, available space, headroom, and position in relation to other appliances.

There is no single formula for capacity, but a basic point is that capacity decreases as oversize fraction increases. This is not always appreciated. Capacity is more related to width than to length, but efficiency of separation improves with the repeated opportunities for passage as the loading lessens toward the discharge end, and travelling particles become more free to move. Screens are usually suspended (preferably on flexible cable) or mounted on a base bolted to the supporting structure or on vibration dampers. The natural frequency of the supports should be at least 1½ times that of the screen at running speed. Optimum slope is that at which the maximum amount of oversize is handled while removing the required percentage of true undersize. To aid this, the bed thickness must allow stratification of fines down to the screen-cloth with adequate mobility. Feed should be delivered across the full width of the screen with sufficient gentleness to avoid wear. If the feed is dry, gravity chutes work efficiently, but should incorporate a stone-shelf to check the entering velocity. Sticky feed is best handled by mechanized feeders.

Where wet sizing is practised, the feed should be slurried at a liquid-solid ratio of 2 : 1 and flushed on gently but uniformly. Skirtings should not be attached to a screen unless the manufacturer can confirm that this dead weight will not upset the balance and bearings. When installing, thought must be given to convenience of access for maintenance and replacements, and this should not be obstructed by badly planned fixtures such as chutes, hoodings, and skirts. Hoods should be mounted separately from the vibrating body, and in fine screening the suction used to remove dust should maintain a downward flow of air.

Principles Governing Classification

In commercial sizing on screens, the particles are presented to a rigid system of gauging meshes which causes separation in terms of one or two dimensions of their cross-section. In classification no such physical restraint is at work. Instead the rate of fall of each particle through a fluid medium is exploited under controllable conditions so as to direct it into either the "oversize" or "undersize" class. The terms "oversize" and "undersize" thus used are not truly descriptive, since classification is a sorting operation, each particle reacting to the resultant effect of the gravitational force pulling it downward and the frictional and kinetic arresting forces generated during this fall.

If it is heavy enough a particle can fall to the discharge gate at the bottom of the classifying vessel. If of intermediate mass it is held in the teeter column. If light it is swept out with the overflowing fluid. The vertically acting force is hydraulic and is provided by the velocity of rising water. The strength of

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the force is determined by the speed at which this water passes upward through the horizontal cross-section of the classifier at a given point. This in turn is a function of the volume of rising water and the free area at the cross-section, part of which is occupied by grains of mineral in teeter. If a particle is to fall under these loading conditions it must overcome frictional drag and collision in the teeter zone. Under these circumstances it is said to be separated by *hindered settling*. If the classifying vessel also imposes horizontal flow on its contents, a falling particle is displaced from the vertical to a distance proportional to the time it has taken in passing through the current. A pulp of water and fine particles is the classifying fluid normally used in mineral processing. Fine, dry powders can be classified in vertical or horizontal air currents.

Classification deals with a mass of small particles in movement varying from slight drift in parts of the mass to turbulence in other parts. An individual particle is constrained by the packing density in its immediate neighbourhood. If this is thought of in terms of the number of particles in a unit volume of pulp (termed by the author the *specific population* in order to tie up with the frictional factor of *specific surface*) it can be seen that a pulp has a critical concentration below which unimpeded motion of individual grains occurs and above which increasing intergranular interference is encountered.

The factors which influence movement of particles relative to the surrounding fluid may be summarised:

(*a*) The relative velocity of particles of the same S.G. and shape varies as their sizes, a larger falling faster than a smaller one.
(*b*) With two particles of the same size and shape, but of different densities, the heavier falls faster.
(*c*) With two particles of the same S.G. and size (displacement), but of different shapes, the fall is retarded by skin-friction relatively to their surface areas. (Maximum falling rate is developed by a sphere, minimum by a thin plate.)
(*d*) Resistance to fall depends on the velocity of the falling particle (Newtonian, intermediate, or Stokesian) and varies directly as the velocity when slow-falling through an intermediate zone of change till it varies as the square of the velocity when falling rate is higher.
(*e*) Other things being equal, the velocity of fall varies as the squares of the particle diameters when these are small, as the square roots of the diameters when larger.
(*f*) Resistance to fall increases with the S.G. and viscosity of the fluid medium through which fall occurs.
(*g*) Anomalies in behaviour may arise through flocculation, or the presence on the particle of minute air-bubbles.
(*h*) The degree to which individual particles can develop their shape and mass properties is conditioned by the *specific population* and *specific surface* of their environmental pulp.

Though this matter is discussed more completely in the chapter dealing with concentration by gravity methods, it is helpful at this point to note certain ways in which gravitational forces act selectively in classification. When grinding has liberated a heavy particle and a similarly sized light ent. item (*b*) of the above list provides a simple means of seperating em. If the two particles are introduced into a vertical current of water, which flows upward faster than the light particle would fall through still water but slower than the falling rate of the heavy particle, then the one will drift upward with the current while the other will fall slowly downward. Here, if a feed were sized on screens and then presented to some such system, efficient concentration would result. Removal of the variable of *size* would develop a maximum difference in behaviour due to *density*. If the order were reversed, it might be possible to cause small heavy particles to fall at the same rate as big light ones, and then to separate them on a screen of intermediate mesh, or by other methods if they were too small to screen. In this case a *classifying* difference would be removed in order to develop maximum response to a *sizing* difference.

Since classification depends partly on frictional retardation, it cannot be applied effectively to coarse material. It takes over from screening somewhere below 20 mesh, and is used on free-falling or "hindered-settling" particles down to sizes of a few microns, the range being extended further when required by the application of centrifugal force.

The mixture of fine particles with water acts as a heavy liquid. Its density depends on (*a*) the specific gravity of the ore from which the fine particles have come and (*b*) the solid-liquid ratio or percentage by weight of solids in this fluid mixture. When a particle of relatively coarse size falls through this fluid, it converts its potential energy to kinetic, its motive power being the difference between its weight and that of an equal volume of classifying fluid. Hence, the higher the ratio of solid to liquid the smaller becomes the gravitational effect. In one form of classifier (the free-settling mechanical type) fluid density is an important controlling factor in maintaining the desired separation of undersize from oversize.

The kinetic energy of the particle, as it is generated, is used not only to overcome viscous resistance in the fluid but also (if the particle attains sufficient speed) to start vortexes and to displace other particles during collision or frictional contact. It has been convenient to consider a single particle dropping through the fluid, but myriads are moving in all directions in the classifier, and their individual collisions and reactions are far too complex for mathematical resolution. Fortunately, the resultant of all these collisions and rubbings is a generalised effect sufficiently controllable to be of the greatest possible value in the fine grinding of ore. There is no precise cut-off point in classification such as can be obtained in careful screening, but at a given separation point the bulk of the particles will respond in the desired manner. At the point where the separating cut is being made, some particles will be diverted by drifting vortexes which throw them into the wrong stream, but in milling the scheme of concentration is kept sufficiently elastic to allow for this.

It was noted that large particles fall with some strength while small ones fall gently. Two types of classifying treatment are available for exploiting this difference, and when sorting an ore the one chosen is that which will select the most appropriate product for further treatment. For film sizing or "stream action" (discussed under gravity treatment in sluices and on

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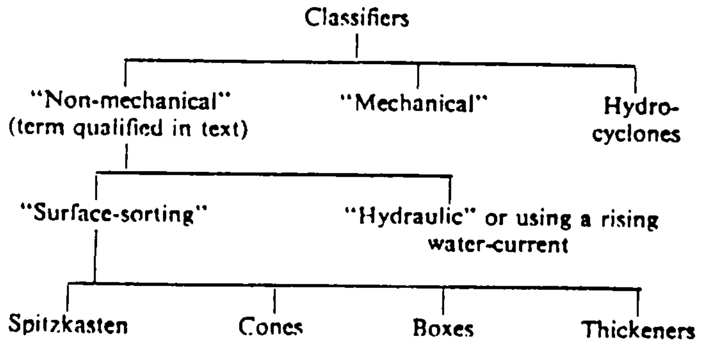
shaking tables) the greater the difference between the sizes of two equal-settling particles, the better will be their separation. Hence, if a sufficiently coarse *break* or liberation grind to give Newtonian settling is called for, classifiers which give maximum size differentiation in their sorting work are used. These are hindered-settling classifiers. When the break point of the ore must be taken at a mesh so fine as to bring the particles toward or into the realm of Stokesian settlement the crowding of the particles through a dense teeter bed, characteristic of the operation of hindered settlers, is too violent to be practicable. A change is then made to a system which permits free settling through a fairly quiet fluid pool, in which the specific population is much lower. This form of separation is used in mechanical classifiers and thickeners. Hindered settlement is used with separating "fluids" carrying from 40% to 70% solids, while free-settling conditions operate with between 3% and 35% of solids in the separating medium. Hydraulic classification is applied to the sizing of homogeneous fine gravels and sands, to settle a relatively fast-settling coarse fraction from a slower one. Classfiers (including *thickeners*, which exploit a more slow-moving variation of the same principles) are used for a wide variety of purposes, including sizing, sorting, desliming of foul effluents, dewatering muddy pulps, adjusting the solid-liquid ratio of a pulp, and development of greater response of ground ore to concentrating processes.

Spitzkasten and Settling Cones

Many special developments of the general principles of classification exist, but it is possible to separate these into groups, despite some obvious overlaps.



Since powered mechanisms are applied to specially developed sub-types of the so-called "non-mechanical" classifiers, this term is not strictly accurate. In common technical usage, "mechanical classifiers" are inclined troughs in which part of the pulp settles and is continuously withdrawn by raking, spiral, or other suitable gear, while all other types are classed as non-mechanical, whether motorised or not.

Att[4] groups non-mechanical classifiers into

> ". . . two main types, namely, Surface Classifiers, wherein the sizing is effected at the water surface, by the water which brings the material to the classifier; and Hydraulic Classifiers, wherein it is accomplished in a restricted passage by fresh or added water introduced below. Surface classifiers are employed for finer material, the discriminating velocity being that which wells upward across the relatively extended surface at the level of overflow; hydraulic classifiers are used for coarse material, say above 80 mesh, the restricted passage permitting the requisite rising-velocity to be obtained with no great amount of added water."

The elementary form is the spitzkasten (Fig. 84), a pyramidal box. A stream of pulp flows in at one side, drops part of its solid charge with some water to an aperture at the pointed end, and discharges the remainder *via* an overflow lip. The entering pulp transforms part of its horizontally directed kinetic energy into downward-acting eddies and vortexes. Particles caught up during these shifting and whirling movements acquire centrifugal acceleration, which may throw them out of the vortex in any direction from vertical to horizontal, and this force acts without discrimination on large and small, heavy and light particles. On the whole, the heaviest and coarsest sands gravitate downward to the bottom discharge while the lighter material is crowded back to the top overflow. In its crude form, the spitzkasten does not make a particularly satisfactory separation, but it illustrates the fundamental principles at work, and is therefore worth examination.

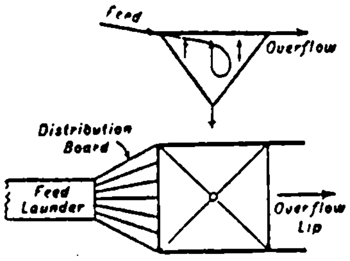


Fig. 84. *The Spitzkasten*

First. As with all classifiers, only two products are delivered. Everything entering must either depart above or below. The greater the proportion of solid withdrawn below, the greater will be the amount of fine material included in it. With feed and discharge rates steady and equal the total number of particles, and their size distribution, is definite. All that can be done in classification is to vary the ratio between the quantity of coarser sand leaving below (*via* the spigot discharge) and the relatively fine overflow. If the spigot were closed, all the pulp would eventually overflow without classification, and this overflow would contain the maximum possible percentage of coarse particles. The greater the fraction removed as relatively coarse oversize the finer must be the average size of both overflow and underflow, and *vice versa*. Separation does not mean that only coarse particles will underflow and only fine ones overflow. This pitfall sometimes confuses the learner, who imagines that if the coarsest particles are being removed from one point the result must be to give a much finer product at the other withdrawing place. What happens is that classifier adjustment simply varies the splitting conditions. Overflow and underflow are respectively fine and coarse relative to this splitting.

Second. Since the volumetric capacity of the spitzkasten is constant, the settling rate available to a particle varies as the volume of feed. Other things remaining unchanged (including the ratio of solid to liquid in the feed), the greater the fed volume, the less will be the dwelling time of each particle, hence the coarser the overflow fraction since it has less time in which to settle.

Third. If the rate of feed is constant, but the solid-liquid ratio varies, the specific gravity of the pulp varies with the increase or decrease in content of solids. Since the rate of settlement varies inversely as the solid fraction, the more watery the feed, the finer will be the average size of overflowing particles.

Fourth. It is customary to consider that classifiers separate particles by virtue of a combined vertical and horizontal movement. To this end, the maximum cross-section is usually provided in the horizontal plane of overflow, and in the surface area immediately adjacent to the overflow lip all particles are deemed to move horizontally. Hence, the argument continues, if in this area the particle is swimming or drifting in the overflowing current, it is carried out of the classifying system. If its physical relation to the system at this point causes it to sink, it is retained and may sink to the underflow zone for discharge in the coarse fraction. Teetering particles are discussed later in this chapter. Hence, the capacity of a classifier is related to its horizontal area in the plane of overflow, and the concept of "surface classification" or "surface-sorting" is closely bound up with pulp behaviour in this plane. In theory, it should be possible to control the density of the pulp at this surface, and also the horizontal speed toward the overflow which influences the drifting rate of a particle. Operation based on these considerations, together with those of mass and surface friction, should lead to an accurate sorting system. In practice, only rough sorting takes place in the spitzkasten. The entering particle undergoes random acceleration, in a confused mixture of interfering vortexes. It passes from one solid-liquid ratio to another in various parts of the box, with varying freedom of packing. Finally it is delivered to the sorting surface with an unpredictable kinetic energy directed at any angle by the vortex from which it is separating at the moment.

Fifth. The shape of the spitzkasten provides quiet zones down the corners, and beds of sand pack into them. Some particles work their way over these beds to the overflow without undergoing sorting action. Toward the continuous underflow, periodical collapse of the packing chokes the discharge orifice, causing surging and abrupt change in the downward flow of pulp.

Appreciation of the foregoing considerations will aid in understanding the physical limitations of classification in the more elaborate appliances discussed later. The first improvement in simple spitzkasten work is to use a series of boxes, increasing in volumetric capacity, so that the coarsest sands

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moved first and the finest last (Fig. 85). To avoid settlement of material on the sides, these are made steep. With the larger boxes this would lead to high pressure on the underflow and the production of too watery a discharge there. This is avoided by using the "gooseneck" discharge pipe shown, with suitable provision for clearing it should "tramp oversize" from a preceding spitzkasten settle in the pipe and choke it. At one time spitzkasten series, either in box or trough form, were widely used ahead of gravity separation, but they are not much seen today. Baffles must not be used with spitzkasten as they would interfere with surface selectivity.

To overcome the surging effect produced by the periodical sliding down of settled sands from the corners of the box, cones are used. Feed is central and overflow peripheral into a launder. If provided with a diaphragm to prevent very fine material from dropping through with the coarser sands, the appliance is called a diaphragm cone, and still further regulation of the solid-liquid ratio at the bottom discharge may be provided by a float system

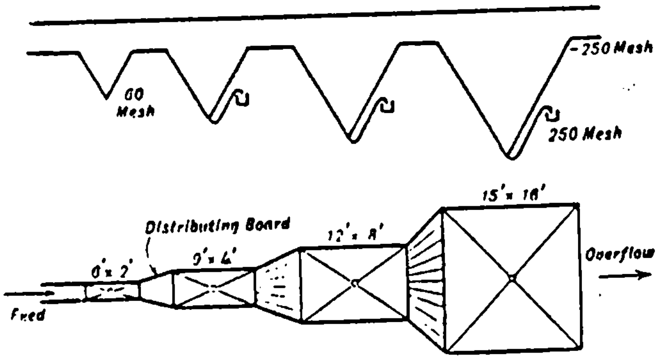

Fig. 85. Series of Spitzkasten (Section and Plan) (after Truscott)

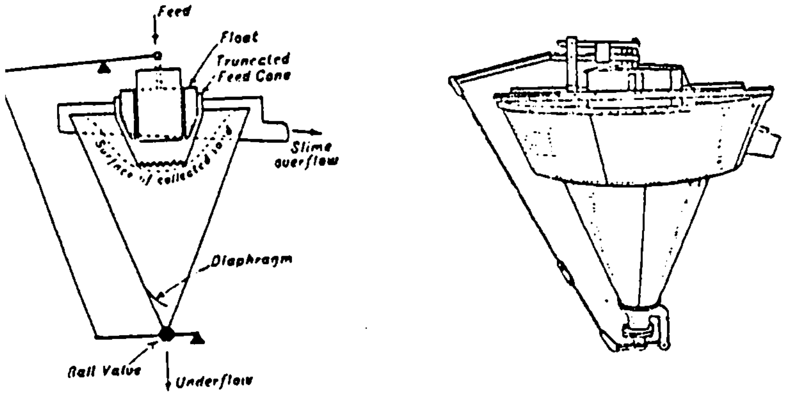

Fig. 86. The Settling Cone

which varies the aperture in accordance with changes in the feed (Fig. 86). Very little classification is done in these cones once sand has settled to a fairly compact mass. The selective action occurs in the fluid layers of swirling pulp above this bedding. Since feed is introduced centrally and the pulp is then swept through a rising path toward the peripheral overflow, the coarsest and heaviest particles tend to drop straight through or to settle out from this eddying stream, while those smaller than a certain mesh are lifted to the overflow lip. The solid-liquid ratio of the underflow depends on the closeness of packing of the settled sands.

Under favourable conditions, the cone compares inefficiently in performance with the far more costly mechanical classifier, save that it is unable to restore the loss of head of the coarse sands dropping through it, and cannot therefore close a milling circuit without the addition of a pump of some kind. It can be used for desliming or dewatering. Simple devices based on the spitzkasten find little application in modern plants, but have a limited field of use in small operations.

Nests of boxes, with either pyramidal or V-shaped settlement zones, were developed for thickening dilute suspension of fine sand, and for reclaiming mill water. They offer a large quiet zone with a gentle motion over the surface-classifying area. They afford a gentler application of the sorting principles at work in the spitzkasten, in the same way that the settling cone does in comparison with the cone classifier. Their place today has been taken by thickeners of the type described in the next section.

The Thickener

Thus far the conditions which affect particles settling quickly from random vortexes and under crowded conditions have been considered. In the thickener, settlement is free and the particles are given hours to gravitate downward. The classifiers hitherto considered were either trying to split a long-ranged feed into coarse and fine fractions in a short time, to trap out coarse sands, or to remove slimes from a fast-settling pulp. When the particles have been very finely ground a prolonged dwelling time under quiet conditions is needed for their settlement. The thickener is constructed with sufficient volumetric capacity to give this time. It can be used:

(*a*) to reclaim water from a muddy effluent by allowing the silt to settle;
(*b*) to decant fouled water or chemical solutions;
(*c*) to change from one chemical wash-solution to another;
(*d*) to remove a dissolved mineral product from a pulp;
(*e*) to thicken (i.e. increase the solid-liquid ratio of) a pulp;
(*f*) to reclaim some mill water before discarding the solids from a tailings pulp.

The essential features of a thickener are shown in Fig. 87. In a typical operation, mill pulp carrying finely ground solids in suspension is fed in centrally, through a "trash screen" which holds back any debris that has accidentally entered. The entering pulp displaces part of its volume as a

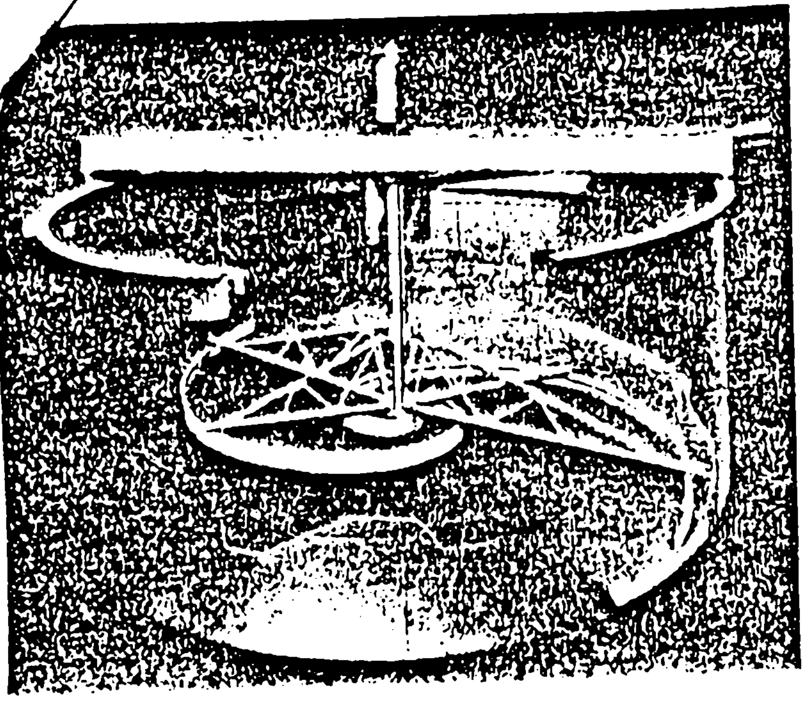

Fig. 87. Cutaway View of Hardinge Spiral Rake Thickener

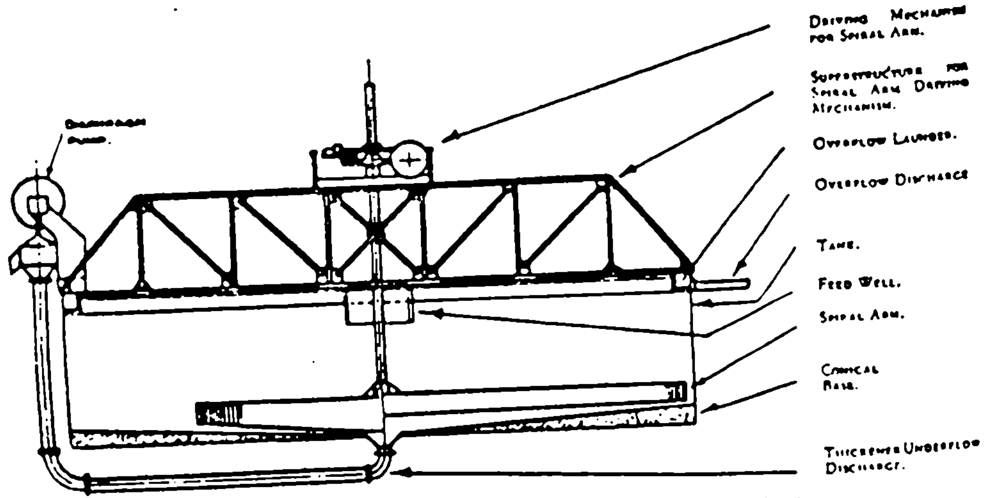

Fig. 88. Hardinge Thickener (International Combustion)

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peripheral overflow of moderately clean water. During the very gentle radial drift of this overflowing water from centre to sides the solids fall slowly downward, perhaps individually, or more usually with some degree of flocculation into aggregates of particles. Material sufficiently coarse falls rapidly to the raking zone below, while the rest of the solid fraction settles and leaves a zone of clear water toward the upper periphery, followed by one similar in consistency to the feed (less its coarser particles). This is succeeded by a transition stage through which the pulp steadily increases in solid-liquid ratio as it settles downward until it reaches the compression zone where the particles, or more probably the floccules, are being squeezed together by the weight of fluid above. Through this compression zone the rakes (in Figs. 87 and 88 the spiral gathering arms) of the thickener are very slowly revolving, gathering and sweeping the settled slurry or slime toward the central discharge well. The rake arms may be revolving once in from two to eight minutes, and as they move, their superstructure cuts through the billowing floccules, opening channels through which clear water can be squeezed upward.

In thickening, flocculation of the pulp is usually an important factor. The subject is considered later. At this point it suffices to remember that the more dilute the entering pulp, the slower it is to form flocs and hence the longer its settlement time. Thus, when a thickener is showing signs of being overloaded (by discharging insufficiently clear water at its launder) the trouble may be due, paradoxically, to insufficient solids in the feed. This is because flocculation depends partly on the opportunity given to particles to collide, which is proportional to their concentration.

The thickener may be a very large round tank, or a cylindrical excavation lined with concrete. It must be capable of containing the continuously entering feed-pulp for the number of hours required for efficient settlement and compression down to the required solid-liquid ratio in the well at the centre of the discharge zone. The bottom of the tank usually has a gentle slope inward to this well. The rakes which gently press the slurry and gather it to the centre may be driven from a shaft, or be towed by an electric motor running round the periphery on a monorail.

In operation the feed rate and feed-pulp condition must be such that there is ample time for a protective clear zone to form and to be maintained toward the launder, while the settling fraction has adequate time to consolidate. The rate of discharge from the well is regulated by means of a diaphragm pump which is run at a rate allowing some two feet of fully thickened slurry to be maintained in the compression zone. This layer holds back the insufficiently compressed pulp and ensures that only a completely settled slurry is withdrawn. If the zone is allowed to become too thick, there is danger of burying the rakes or of overloading them and injuring or distorting the mechanism. Alarm and trip mechanisms are fitted to indicate the advent of such overloads. The overflow can be monitored by an *electric eye* so that warning is given if its turbidity rises unduly. Since the slurry being pumped from the underflow is dense, it is carried through pipes of small diameter to the pump, thus maintaining it in motion sufficiently vigorous to reduce any tendency to settle out and choke the withdrawal system. Flushing points are also pro-

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used through which water or compressed air can be injected in the event of choking. Instead of pumping, some large installations use bottom valves to run slurry off. The piping discharge is then of ordinary diameters. The thickened discharge is commonly led to a continuous filter which must periodically be shut down for servicing. During such a period, which may last several hours, the thickener continues to receive feed and must store its slurry. Provision is made for raising the rake mechanism to prevent overstrain under such conditions. Since this is a safety precaution, the rakes must be gently lowered as soon as normal running has been restored and the loading has been reduced.

Choking around the well of the thickener is a serious matter that may lead to the shutting down of the whole mill. Solid objects fall in, either through sabotage, a kink in human nature, or through failure of workmen on the thickener to tie loose tools to a safety belt. It is therefore a wise precaution to have a run-off tank available into which the contents of the thickener can be sluiced in emergency. If the thickener is "stalled", speedy repair is essential, as there is rarely standby capacity to which feed can be diverted.

Where space is cramped, or where the risk of freezing entails protection, tray thickeners having from two to six compartments are often used. The pulp is divided into equal streams, and each is fed centrally to a compartment. In one type each compartment rakes the settling slurry to a common well-discharge. In another type the slurries can be kept separate. The water overflow rises naturally from the lower trays to join that from the top peripheral launder, or, if desired, these overflows can be kept separate.

Failure of the settled slurry to come away from the well may be due to a solid object obstructing the outlet, a choke in the piping system or a defect in the diaphragm pump, such as a stuck valve or a ruptured membrane. Thickeners receiving a flotation concentrate sometimes build a thick scum of floating froth on their surface. To minimise this, the feed should run in gently, since splashing is likely to entrain air-bubbles.

Little power and attendance are normally required, but when a thickener breaks down it can very seriously upset the running of the plant, since it usually constitutes a "bottle-neck" in the flow-line. To simplify maintenance and avoid a lengthy shut-down thickeners are sometimes built with an approach tunnel below, ending in a pump room. Alternatively, underflow may be pumped up through a central column large enough to permit a man to enter.

Among recent developments in thickener design[5] are a two-stage raking zone. The peripheral area has a relatively shallow gradient, while coarser material which tends to settle more centrally falls to a steeper central portion. The inner rakes which sweep this zone are attached to posts below the trusses. These posts cut through the deposit and open channels through which water can squeeze upward. The trusses themselves are not subjected to the strain of shearing through this material. Another design is a flat-bottomed thickener with peripheral discharge.

Where continuous thickening is coupled with periodic filtration so that storage capacity inside the thickener is required, automation has been successfully used to raise or lower the rakes in accordance with changes in torque

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signalled to a motor which lifts or lowers the raking mechanism. For sub-zero working of exposed plant, electric heating of driving gear and pump room can be used. For a thickener which is used to clarify a thin, but finely divided and slow-settling feed, hydraulic disturbance where the feed enters can be avoided by delivery through vertical screening which divides the flow into a number of thin streams and checks these by baffling.

Thickening Theory

In 1916 Coe and Clevenger[8] produced a formula for calculating the thickener area required in handling a known rate of loading. Their observations were based on the zone sequence seen during the settlement of pulp—clarification of the uppermost layer and increasing pulp density down to the final stage of compression (the critical point) below which no further settlement occurred. Thus at any horizon in the transition zone there was a change in pulp density which affected the subsequent settling rate and the specific population at that horizon. Their calculation of the required thickener area was formulated in respect of a transitional rather than a final or saturated concentration, and within that limitation was dependable. It is

$$A = \frac{1{\cdot}33\,(F-D)}{R\delta} \qquad (9.3)$$

where A is the area (ft.^{2}/ton) of dry solids per 24 hours
F is wt. of liquid/wt. of solid in feed
D is wt. of liquid/wt. of solid in discharge
R is the settling rate and
δ the specific gravity of the pulp.

In 1952 a new approach was made by Kynch[7] in which the original basic assumption (that the settling velocity of a particle is a function of the local concentration of surrounding solids) is retained. Overloading, in the sense that solids arrive faster in the feed than in the fully compressed zone, changes the density values through the compression zone and thus reduce the rate of delivery to the discharge zone. The thickener area required by Kynch's formula is

$$A = \frac{t_u}{C_0 H_0} \qquad (9{\cdot}4)$$

where t_u is the time in days, C_0 the concentration of feed as tons of solid per ft^3 of pulp, and H_0 the height in feet.

Both formulae bring out the fact that (ignoring any effects of flocculation or need for clarification to completely clean water) sedimentation is governed by pool area rather than pool depth. One element in thickening is, however, overlooked by both formulae, as is pointed out by Fitch.[8] As pulp density increases the particles tend to be locked into a plastic structure the yield value of which rises as the percentage of solids increases. Above this fairly narrow zone particles still have some freedom of movement but the zone itself, called by Fitch the "steady state thickening" phase, controls the volume of arriving solids which can get through it. An elusive compression factor is at work, connected with the shearing of the plastic structure of this zone by the revolving rakes of the thickener. These, in addition to moving settled material to the discharge point, cut channels through which clear water can be seen to well up as it is squeezed out by the heavier settled pulp. This zone is called "the zone of rake action" and the final solid/liquid ratio possible in thickening takes this into account in testing for design of a thickener for a given pulp by using slow stirring of the bottom layer of a sedimentation column in order to provide a channel for this final squeeze-out of water.

As the result of laboratory tests Cross[9] concludes "that the use of a deep, slotted feed well will increase the capacity of a thickener and that the principles originally put forward by Messrs. Coe and Clevenger are no longer tenable. The re-designing of raking mechanisms is called for in order to both cope with the increased tonnage and impart greater movement to the compacting sediment."

A mathematical model of the thickening process has been developed by Gaudin and Fuerstenau.[10]

Hydraulic Classifiers

These appliances are also called "spitzlutten" and upward-current classifiers. In its simplest form (Fig. 89) the hydraulic classifier resembles the spitzkasten, with the essential difference that, in addition to horizontal sorting at its maximum cross-section where the lighter particles overflow the discharge lip,

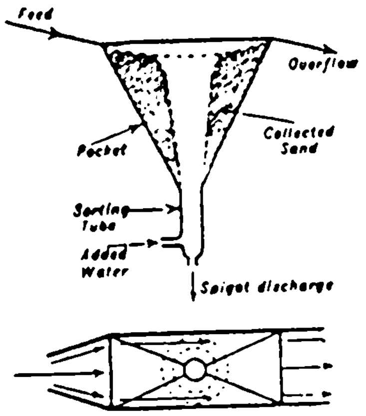

Fig. 89. The Hydraulic Classifier (after Truscott)

there is now added a column of water rising at a controlled rate. A single particle falls through a still column of water at a speed resulting from the gravitational pull downward as moderated by consumption of energy in overcoming shear or turbulent resistance set up by its motion.

Consider three particles which have accelerated to their maximum steady rate of fall through such a column, and which differ in terminal velocity. If the water is now caused to flow upward, a rising velocity can be chosen which neutralises the downward rate of the medium of these particles so that it hovers. The slowest one now rises slowly while the fastest one drifts slowly downward. This is the principle applied in hydraulic classification. The sorting column is usually of even vertical cross-section so that there is no variation in the rising velocity. When the cross-section of the sorting column varies from a maximum at the upper discharge end to a minimum at the lower, it is possible to arrange the flow rate so that similarly energised particles hover on reaching a point where their falling velocities are balanced. Actually, the water does not flow smoothly, so such particles will dance or "teeter" in the column. Thus, two types of construction are possible. In the "free-settling" hydraulic classifier a particle heavy enough to fall goes right through to the bottom discharge. In a "hindered-settling" classifier it may fall to a certain distance and there teeter at the entrance to a more restricted column through which water is rising faster.

In the classifier many millions of particles are simultaneously being sorted. All are jostling against one another to some extent, and at any cross-section of the sorting column the liquid is rushing through the interstices between the tossing and tumbling grains. Thus, the kinetic energy of the falling particle is being dissipated by friction and collision, and the liquid cross-section is constantly varying, giving rise to spinning motions which may equally well impel a particle upward or downward. Only particles decidedly heavy can force their downward way through such a scouring crowd. A heavy particle can be "rafted" clear across and out of the system, by some accident of momentary turbulence. It is easier for a particle to become arrested and entangled in the teeter bed than for it to get out again. In consequence such a bed grows as the hindered-settling classifier works, till the point is reached where the sides are comparatively packed by slowly circling grains moving in vertical ellipses or occasionally sliding down to the discharge. Meanwhile, the centre is occupied by a more mobile teeter column dilated by the rising water. This is indicated in Fig. 89 by the clear central portion of the classifier, which in operation would be occupied by a teetering column of sand giving way (shaded portion) to packed sand at the sides. Here the bulk of the sorting of new feed is done. The central column is a pseudo-fluid of density corresponding to its solid-liquid ratio, which works against the attempt of a heavy particle to fall through. If the feed can travel downward at this pulp density and against the hydraulic rise through the teeter, the jostling it encounters may retard, but will not stop, its descent.

Hydraulic classification may be used as a sizing method, if applied to particles of the same specific gravity. In this case the bigger and heavier ones fall through, given suitable adjustment of the restraining forces, and the lighter ones are carried up and out. Such work can be done with less

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sion, but far more cheaply, than on the delicate fine screens which would otherwise be needed. With sufficiently fine particles, classification can be performed in columns of air instead of in liquid.

In mineral processing the main purpose of classification is to sort a feed into two classes, settling and rising. If this feed contains heavy and light mineral, small heavy particles will have the same falling characteristics as larger light ones. They can therefore be dropped together and then separated on a screen of an appropriate intermediate mesh.

Many shapes and varieties of hydraulic classifier have been developed. Truscott[4] observes in his text-book:

> "Hindered-settling classifiers are those wherein . . . water rises through the sorting tube or orifice into a chamber so dimensioned that the material collected there is brought into a quicksand suspension or 'teetering' movement. The (horizontal) area of the teetering chamber should not be greater than about four times that of the sorting passage or some of the material will lie quiescent; nor much less, because then the conditions of the ordinary free-settling classifier would be approached. With these conditions fulfilled and where particles of varying density and size are present, another specific advantage of hindered-settling is realized, namely the small dense particles fall with much larger less-dense particles than under condition of free fall; with quartz and galena, for instance, the diameter ratio of equal-falling particles under hindered-settling condition is about 6:1—as though the specific gravity of the medium in which fall took place were about 1·5—instead of 4:1 which obtains in free-falling conditions. Of such an increased difference in particle-diameter, advantage may be taken in the processes of separation. . ."

The teeter column thus heightens the separating effect based on exploitation of differences in mass and S.G. It also has a scrubbing action which aids in cleaning the discharged product that runs the gauntlet. This scouring arrests fine particles which otherwise might be carried, attached to larger particles, to the lower discharge. The hydraulic column must be steady, and is therefore fed from a constant-pressure source of water. Some water is withdrawn with the solids leaving at the bottom discharge, and the rest is discharged as the overflow, together with the water in the original feed. Classifiers can be arranged in series, to give progressively finer underflow products. They may receive feed from a desliming cone, or send out a final overflow product for quieter sorting in such a cone. The coarser the desired underflow, the more strong must be the rising current.

The teeter bed is intermediate in settling character. It tends to build up so as to alter the character of the products discharged through it. To minimise this defect, a class of hydraulic appliances having the general distinguishing name of "hydrosizers" has been developed in which this teeter bed is controlled as to composition. As the bed builds up, the weight of its component quicksand also increases. This can be measured by providing a water connection in the form of a hydrostatic head which shows changes in the back pressure exerted upon the entering hydraulic water (the "added water" of Fig. 89). Appropriate control mechanism can be actuated by pressure changes as in the Stokes hydrosizer (Fig. 90) in which the bottom discharge aperture is opened or restricted in response to changes in the load of teetering sands. This classifier is one of several made in multi-spigot form, to deliver a series of graded products.

Another form of hydrosizer takes the shape of a miniature thickener. Its rakes rotate fast enough to loosen up the settling sands and upward currents may be imposed upon the contents of the circular tank. By suitable use of these combined forces very fine material is caused to overflow, while denser particles drop and are raked to a central well-discharge.

Mechanical Classifiers

In the so-called "mechanical" classifier the pulp is fed into a rectangular tank under conditions which allow the heavier and coarser solids to gravitate fairly freely downward, while the lightest particles flow to a weir discharge.

The "mechanical" part of the classifier is usually a drag belt, a set of rakes, or a spiral screw. Its functions are to stir the pool of pulp and remove settling solids. In Fig. 91 a cross-section through the type of tank usual with a Dorr (rake), Akins (spiral) or drag-belt classifier is shown, without its mechanism. The pulp overflowing from the grinding mill carries 70%-80% solids, and flows to the classifier through a short launder, or possibly after elevation through a centrifugal pump. *En route* or in the tank more water is added, so as to thin the pulp to an operating density at which overflow of finer sands and settlement of coarser ones are most effectively produced. In the launder the pulp stream is split into two or more channels which distribute the feed fairly equably across the pool, approximately two-thirds of the distance from the weir in direction of its "V" end.

Ignore for the moment the stirring effect produced in this pool by the raking gear. The pulp, diluted to say 30% solids, falls from a slight height into the shallow end of a wedged-shaped body of fluid. The height of the feed launder above the pool determines the kinetic energy with which this plunge is made. Rate of settlement through the pulp results from the interplay of complex forces. These may include *thixotropy*, adhesion and cohesion, which receive further discussion in Chapter 15. These forces influence shear in the body of the pulp under stated operating conditions (mainly concerned with temperature, *specific surface* and turbulence). For convenience of operating control this complex is treated as a simple S.G. effect for which the classifier pool is held at a specified operating density. This determines the resistance to settlement which is offered at successive horizons to the particle as it seeks to gravitate downward. There are two channels of escape from the pool. A particle having sufficient mass to force a passage to the bottom, or raked zone, falls and is quietly withdrawn by the mechanical withdrawing device (not shown in Fig. 91). A particle which has insufficient mass to descend can drift with the current from the feed launder to the overflow weir through the transporting zone. Equal-settling particles will report together. A small heavy particle will settle with a larger one of lower density

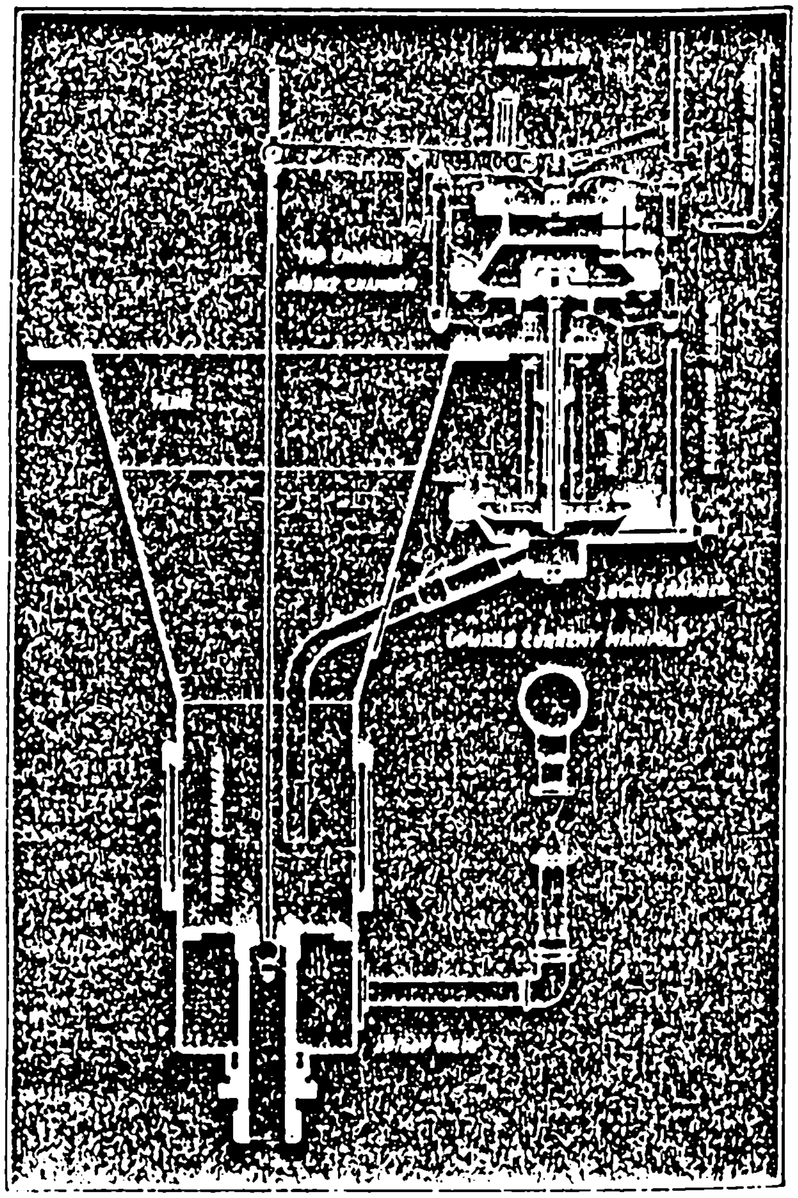

Fig. 90. Section through Stokes Hydrosizer showing Relay Valve

If all particles in the classifier were equal in size, a clean separation into heavy (sinking) mineral and light (overflowing) mineral would be possible. In fact, the mechanical classifier tends to retain the heavier mineral in the ore and return it, *via* the raking mechanism to the feed end of the mill with which it is close-circuited even when the operator desires it to be sent on. The particles comprising the solid fraction of the feed cover a wide range of sizes, and are in various stages of liberation. Consequently some are swift to drop, some slow, while others build up in the sorting zone. This zone is not homogeneous but thickens from the most watery layer at the top of the pool, by increasingly dense strata, to the densest part of the pool immediately above the raking zone. These strata are stirred by the rakes or spirals as they move in the pool of the classifier. Below the rakes lies an undisturbed stratum which packs the clearance space down to the steel bottom of the tank.

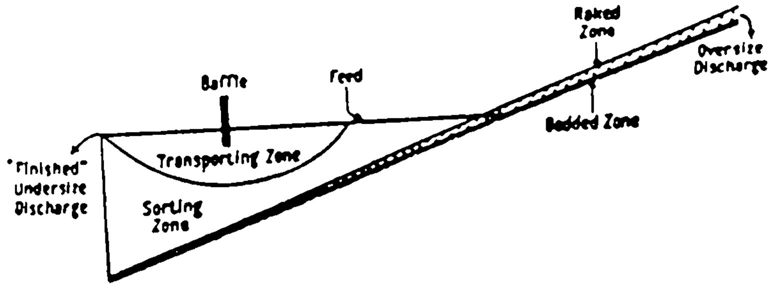

Fig. 91. *Cross-section through Classifier Tank*

It follows from this sorting of the pulp into zones that each layer continuously receives new particles from above, and either (*a*) lets them fall through, (*b*) rejects them back to the layer above it, or (*c*) retains them. So long as a layer only sorts the entering particles according to (*a*) or (*b*) it retains its integral composition and performs consistent and predictable work. When, as is inevitable, it captures more particles, it increases its density and any further entering particles must be correspondingly more dense in order to fall through. To some extent this continuous rise of pool density is offset by the stirring action of the rakes, by the downward drift of the sinking particles, and by the slow horizontal displacement of the rest toward the weir discharge. These movements alone are not able, in the ordinary classifier, to maintain a constant distribution of strata densities in the sorting and transporting zones, though they can be helped considerably by skilled operation.

The bed below the rakes often traps the heaviest particles fed to the classifier. If these constitute a valuable product such as free gold, an undesirable concentration of material will result. In some grinding circuits small concentrating devices are set between mill discharge and classifier to "*scalp out*" such heavy values.

The rate of movement of rakes or spirals can be varied to produce the required turbulence in the pool. With a mechanical classifier set to yield a fine overflow this might be as low as 9 rake-strokes per minute when making a separation at —200 mesh, varying up to 32 or so for 28 mesh, rapid-settling sands. The rakes have the further major function to perform of clearing the settled sands up-slope to the mill feed launder, and they must therefore be run at a speed which deals adequately with the load falling to them. A section through the Dorr rake classifier is shown in Fig. 92. The rakes (1) are set in an inclined tank and are actuated *via* an eccentric motion (8) and two sets of link motion, 9 to 13, and 3 to 6. These links cause the rakes to moves through an elliptical orbit, almost flat on its long axis which corresponds with the slope of the classifier tank. The rakes start their climb at the lowest setting, and gather settled sand. At the rising end of the stroke they lift sharply. They then return, drop, and repeat the cycle. These classifiers are described as simplex when the trough has one compartment, duplex and quadruplex when there are two and four divisions separately raked. Provision (not shown) exists for raising the rakes. Spiral classifiers (Fig. 93) do not normally set up a turbulent stirring action in the classifying pool, but cross-pieces can be bolted to the spiral shoes to produce this. The helix

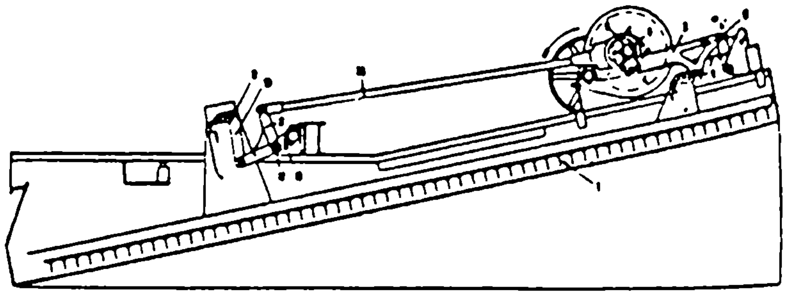

Fig. 92. Cross-section, Dorr Rake Classifier

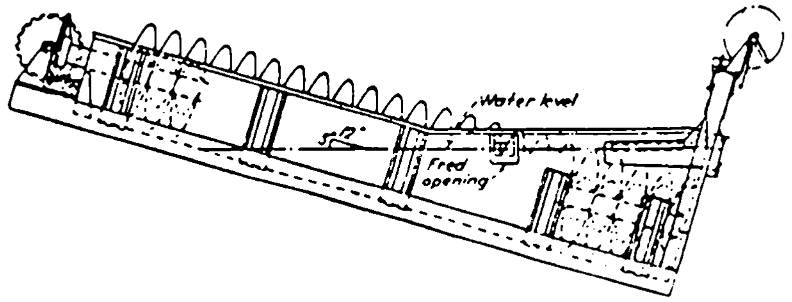

Fig. 93. The Akins Classifier

is run at a speed varying with its maximum diameter, the shaft usually turning at between 3 and 6 r.p.m. for a large spiral, and up to 20 r.p.m. for a small one.

As settled sands emerge from the "V" end of the pool, they bring with them some trapped or "drag-out" slime which should properly have overflowed at the weir. Washing sprays are often used to return this material to the pool. They offer a simple means of adjusting the pool density by providing a region where extra water can be mixed in, but are not very efficient as deslimers. With the rake classifier the emerging sands usually take an undulating contour, and if the sprays are allowed to play over a length of rising sand the slime is trapped in the depressions, ploughed under at the next dragging up-stroke, and thus smuggled through. To be effective the sprays must be directed forcibly on to sands close to the point of emergence, and other methods must be used for making final additions of water to the pool as the sprays must run at full pressure. In this respect the spiral classifier is at an advantage. It carries its sands upward on the rising side of the helix, so that sprays can be used at any point and there is a good channel for running their washed product straight down to the pool. The churning of newly emerged sand by sprays causes it to slip back and interferes with the elevating function of the rakes. Sufficient height must be gained for the sands to run by gravity back to the feed scoop of the mill, after they fall from the classifier into the return launder. The continuous and more gentle action of a spiral makes possible a steeper slope in the classifier tank, settings of from 3" to 4" per linear foot being common as against 2" to 3", with an occasional 3½", for reciprocating rakes. Removal of slimes reduces the tendency to slip, but a certain amount of deliberate inefficiency is liked by some millmen, who consider that the slime has a valuable lubricating effect in the feed trunnion of the ball mill, and that without it the mill could not handle so large a circulating load. In the "Overdrain" classifier a drag belt moves between stationary longitudinal walls (called shrouds) so as to carry material trapped between successive moving sections in bottomless compartments. From these compartments supernatant slimes overflow through side openings and back to the pool between shrouds and sides of classifier.

In the event of power failure, or shut-down, care must be taken that the raking gear does not become buried as the sand settles compactly down. Reciprocating rakes can be raised in some models, and spirals can be swung clear. If a classifier is restarted with buried rakes, the mechanism may be injured. Rakes and helixes wear, and are renewable.

If tramp oversize or steel from the mill overflows to the classifier, it may lodge so as to project from the bedded zone. This causes rough action and undue wear of the sand-moving mechanism. Spiral edges can be notched, or given welded projections to dig such material up and get it back to the mill.

The separating point can be up to 28 mesh, or anywhere between this and *minus* 200 mesh. Several factors are used in setting the machine to deliver at and around the required mesh. Since a particle must rise from the body of the pool in order to overflow, the upward current in the vicinity of the weir is one determinant. This weir, which is adjustable for height, is at the deep end of the pool. The upward (hydraulic) current can be varied by the introduction of a baffle (see Fig. 91). The deeper this is set, the deeper the transporting current is forced before an upturn in the flow stream of pulp can take place. The distance between baffle and weir determines the cross-section of the rising column, and therefore, the rising speed of the transporting current. For a coarse-grained overflow the baffle may be set as close as 1¼″ from the weir, and for finer separations as far back as 24″. It may be removed altogether for very fine work.

The finer the *release mesh*, the longer must be the settling time given to the entering feed and the gentler the stirring. The volume of pulp available for sorting purposes is therefore an important factor. It is affected by the slope of the tank bottom, the height of the weir, and the width of the classifier. Usually the slope is made as steep as is possible without risking slip-back of raked sands, in order to obtain maximum elevation. This aids their drainage and allows the use of a steeper fall to the feed box of the ball mill from rake discharge into the return feed launder.

Consider a classifier set with a slope of 3″ in the foot, and with vertical walls. The enclosed pulp has a wedge-shaped volume and a triangular longitudinal section. When the weir overflow is raised, the progressive increase in the volume of the pulp is proportional to change in longitudinal area (Table 15).

TABLE 15

Weir Height	*Longitudinal Section Area*	*% Increase*	
8 Units	128	Unity	On previous figure unity
9	162	26	26
10	200	56¼	23
11	242	89	21
12	288	125	19
13	338	164	17½

The effect is to give each particle entering the pool a corresponding overall increase in settling time.

The weir height affects the capacity in the pool. It also influences the total area of horizontal cross-section in the plane of overflow. When the weir is high, it damps the surging motion set up by the plunging movement of the reciprocating rakes of the Dorr-type classifier. The greater the tonnage the classifier is handling, the bigger should be the pool, and hence the higher the weir setting.

Lowering the weir helps when a denser overflow is needed. Care must be taken, particularly when fine pulp is being sorted, not to reduce the capacity of the pool too severely or cyclic surging may become excessive. This would allow sands to escape from the closed circuit before they had been reduced to the proper overflow-mesh, and lead to trouble in the concentrating section of the plant. Consider the classifying zones shown in Fig. 91. When no baffle is used, the transporting zone merges layer by layer into the sorting zone.

Think of the pool as it would be under conditions of smooth and steady flow, with no stirring action from rakes to break up the stratification. It would soon arrange itself in a series of thin layers, sorted from the vertical cross-section of the feed and becoming more individualised as they flowed toward the weir. The surface layer would have a density approaching that of water and the bottom layer that of a high solid-liquid ratio. Further, the grain size of each mineral would be highest at the feed end and lowest at the weir end, because of the combined effect of gravity and rate of drift upon the particles moving in or through the layer. (This discussion temporarily ignores two factors—the upthrust of the layers at the weir end and the accumulation of newly arriving particles at the bottom of the pool.)

An individual particle moving in such a layer can drop through, if its gravitational force is sufficient to overcome its frictional retardation, during the period of its travel from feed to weir. It can rise into a less dense layer through eddying or if it is squeezed up and out by heavier particles. Each of the lower layers is continuously receiving such particles as they drop downward, and receives a greater load than it can part with by rejection upward, or downward, of a corresponding weight of solids. Thus the near-release particles accumulate, and the sorting zone becomes too dense to work properly. The generalized effect is that a rise in the overall density of the pool occurs, accompanied by an increase in the *pseudo-viscosity* so that new feed finds it increasingly difficult to fall through. This can be seen in operation particularly in a circuit set for fine grinding such as is frequently closed by a bowl classifier. The level of the pulp in the main tank rises and falls in a cyclic rhythm, corresponding to a gradual rise in the overall specific gravity of the pool. This is periodically relieved by a surge of heavy pulp over the weir and a drop in the overall S.G. The word "overall" includes normal running density and the heightened one of the high-density surge period, since there need be no change in that of the overflowing pulp during the period of build-up. This would be particularly the case if little or no use of a baffle was made, as the lightly loaded surface layers of the pulp would be disproportionately represented in the samples used to check the specific gravity. For this surging to occur, more solids must arrive in the pool than are departing. During the rise, the rakes become more lightly loaded although no change has been made in the rate of new feed to the mill. If at this stage vigorous action is taken to dilute the body of the pool (say, by directing a jet of water into it), the rakes load up to normal, or beyond, and proper recirculation is restored.

This phenomenon only becomes serious when the mill has insufficient classifier pool capacity for its input of ore. These layers can to some extent be mixed by raking, or by setting up turbulence in other ways, e.g. by allowing the feed to plunge into the pool from a slight height. When water is added to reduce the density of the pool it should be mixed in, not simply used as a spray wash on the raked-up sands. Unless it is mixed in, it may run as a lightly loaded layer above the sorting zone, simply washing out some fine material by its streaming action. The use of the baffle forces all surface water down into the body of the pool and aids such mixing. Provided the diluting water is properly mixed in—partly in the feed launder and partly in the body of the pool toward the weir end, the density of the overflowing pulp becomes the vital operating control. If this mixing is not assured, the value of the control is weakened.

There is a certain ratio of solid to liquid, called the critical density or the critical dilution, above which the size of particle overflowed depends upon the pulp density in the upper part of the pool. If the pulp is diluted below this critical density, the particles no longer respond significantly to this form of control. The critical density varies with the ore, temperature, and the flocculating effect of chemicals such as lime which are frequently added in the grinding circuit for reasons explained in the chapters dealing with flotation. Broadly, the percentage of solids at which change is to be expected is somewhere between 3% and 5%. The most important factor in this critical density is pseudo-viscosity or specific particle surface. A given ore has a critical density proportional to the square of the particle mesh for a given solid-liquid ratio since this governs the total area of surface in a given volume of pulp. If the feed contains clay or other primary slime, the critical density is lower, because the pseudo-viscosity is higher.

Provided the solids which should be returned to the mill for further grinding are able to fall through to the raking zone, the speed at which the rakes are run depend on:

(*a*) the degree of turbulence desired in the pool to break up the layers as they try to form;
(*b*) the amount of raking needed to withdraw settled material.

Some confusion exists in the minds of learners with regard to this. It is sometimes argued that classifier capacity can be increased by increasing the rake speed and hence the rate of withdrawal. Any increase thus obtained would be temporary. The material raked up returns to the mill, where it displaces an equal volume of crop load. All of this comes straight back to the classifier, so the only effect of faster raking could be to increase the classifier feed by the same amount. It is unlikely that this would in fact happen. The rakes can only remove the sand falling to the raking zone, and this is partly regulated by the sorting rate in the pool. In practice, the new feed to the mill is so regulated as to keep the rakes well, but not excessively, loaded. Since the circulating load usually exceeds the tonnage of new feed, any change in the raking speed affects the dwelling time of material in the grinding zone of the mill. This is controlled to an optimum time, and changes in rake speed are therefore only made as the result of tests. This also applies to changes in the weir height and position of the baffle, if one is used. Such changes should only be made after studying screen analyses made in the laboratory.

All Dorr classifiers can be fitted with a shallow bowl (Fig. 94) in which gathering rakes revolve slowly—2 r.p.m. being usual—so as to move settled material gently toward the centre. The feed from the mill is introduced centrally, and spreads radially, thus giving a greater surface area from which the particles can drop from the outward streaming pulp. The bottom of the bowl is a shallow cone dropping 2½ in./ft. The return sands are drawn to a slot, through which they drop to the raking zone of the standard Dorr classifier below. Owing to the loss of head in this arrangement, it is not normally possible to close a circuit containing a classifier bowl unless a low-head centrifugal pump is used to elevate the mill discharge ahead of the classifier. A modification, the "bowl desiltor" has been described by H. W. Hitzrot.[1]

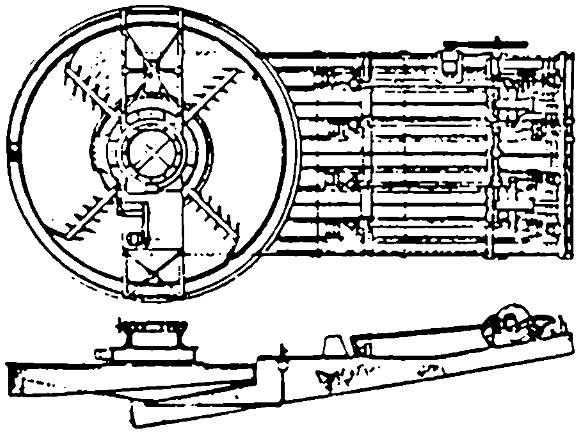

Fig. 94. Dorr Bowl Classifier

In another proprietary make (Fig. 95) when fineness of grinding necessitates the use of more surface settling area than can be provided in the ordinary mechanical classifier, a bowl somewhat like a miniature thickener is used. This, the hydroclassifier, works on lines similar to those of the Dorr bowl.

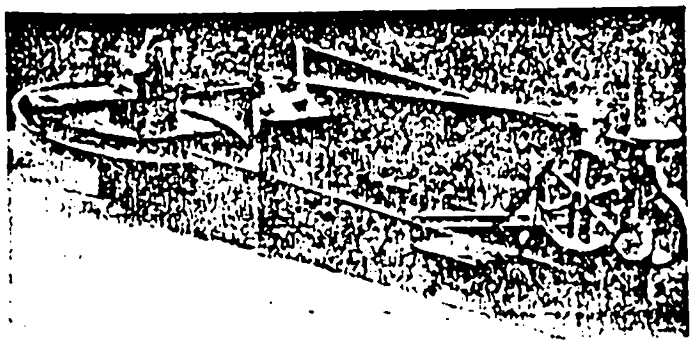

Fig. 95. Denver Bowl Classifier

Such a machine can also be used independently of mechanical classification. Hydraulic water may be introduced where the hydroclassifier is acting as a deslimer.

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Except when the mechanical classifier is overloaded and is improperly surging part of its undigested load over to the concentrator in an unfinished condition, this class of machine makes no middling. The feed is split with moderate efficiency into two fractions. These are either fine plus moderately fine, or coarse plus moderately coarse. They cannot be fine and coarse, since the use of controls to separate a fine product at the weir means that the bulk of the entering feed must have been ground fairly fine. The higher the specific gravity of the ore treated, the higher must be the pool density for a given discharge mesh.

Other classifiers include the Dorr multizone, the hydro-oscillator, and the Hardinge (Chapter 12).

Centrifugal Classifiers

The rate of fall of a particle varies as its effective mass. If centrifugal force is applied, the effective mass is increased and, provided nothing happens to offset this effect, settling rate is higher. As particles are ground smaller they reach a size where the surface drag against the surrounding fluid almost neutralises the gravitational pull, with the result that the particle may need hours, or even days, to fall a few inches through still water. This slowing down of settling rate reduces the tonnage that can be handled and increases the quantity of machinery and plant required. A 10μ particle of silica settles through water at speed varying round 6 mm./min. which, for many purposes, would be too slow. By superimposing centrifugal force the gravitational pull can be tremendously increased.

The Hydro-Cyclone

During the past few years cyclones have replaced mechanical classifiers in many grinding plants. The liquid-solid cyclone (this name, and the prefix "hydro" usually being omitted) was introduced by Driessen in 1939, and the references[11-18] indicate only a fraction of the literature already published concerning its principles, applications, and performance. When a pulp is fed tangentially into a cyclone (Fig. 96) a vortex is generated about the longitudinal axis. The accompanying centrifugal acceleration increases the settling rates of the particles, the coarser of which reach the cone's wall. Here they enter a zone of reduced pressure and flow downward to the apex, through which they are discharged. The percentage of feed leaving as coarse product depends on the aperture of the inlet and vortex finder provided the underflow does not exceed some 30% of the feed. At the centre of the cyclone is a zone of low pressure and low centrifugal force which surrounds an air-filled vortex. Part of the pulp, carrying the finer particles, moves inward toward this vortex and reaches the gathering zone surrounding the air pocket. Here it is picked up by the tube called the vortex finder, and removed through a central overflow orifice. The vortex finder is so adjusted as to project into the cylindrical section of the cyclone, and short-circuiting of

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newly arriving pulp is thus minimised. The main controlling factors in cyclone operation are:

1. Feed Inlet Diameter.
2. Feed Pressure.
3. Feed Rate.
4. Solid-Liquid Ratio.
5. Position of Vortex Finder.
6. Diameter of Vortex Finder.
7. Diameter of Apex.
8. S.G. of Solids in Feed.

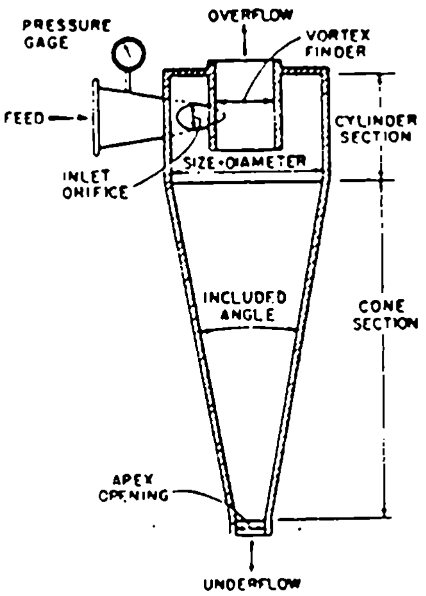

Fig. 96. Cyclone Nomenclature

Dahlstrom has produced an empirical equation.

$$D_{50} = \frac{97(bc)^{0.68}}{Q^{0.53}\sqrt{P_s - P}} \qquad (9.5)$$

D_{50} = 50% particle diameter (μ)
b - cyclone inlet diameter (inches)
c cyclone overflow diameter (inches)
Q = Imperial gals./min. of feed.
P_s & P are S.G. of solid and liquid in gm./cc.

The 50% particle diameter is further defined as the equilibrium particle size at which centrifugal and centripetal forces in the cyclone are so balanced that half the solids are discharged as the coarse fraction (apex discharge or underflow) and the rest *via* the central overflow.

Q in this equation is a function of inlet diameter, overflow diameter, pressure drop in transit and a constant *K* which varies with the included angle of the apex.

Tarjan's equation[17] for the size of particle which revolves in equilibrium at the circumference of the cyclone cylinder is

$$d = \frac{42e^2}{\sqrt{(P_s - P)\,h\,Q}} \qquad (9.6)$$

where h is the height of the cylinder in cm., e is given in cm. and Q in l/s. son Fahlstrom observes that the hydro-cyclone has two sets of characteristics. First are the ones fixed by construction—diameter, area of feed entry, length of drum and vortex finder, and cone angle. Second are the operating variables which include pulp concentration, feed pressure, diameter of overflow pipe and of vortex finder. The effect of the classifying action can be defined in terms of weight of yield and of percentage of solids in the underflow. Separating size is given by his equation

$$\delta = k_n\,(1 - g_u)^{1/n} \qquad (9.7)$$

and maximum sharpness of separation by

$$\eta\ \text{max.} = 1 - v_i\,(10 - 16{\cdot}7\ v_u) \qquad (9.8)$$

where δ is the size of separation, g_u the weight yield at underflow, k_n and n constants characteristics of feed size, η max. the sharpness of separation and v_i, v_u pulp density and parts by volume of solids in the feed i and apex discharge u. Precision of separation (η max.) is highest when v_i and v_u are related to the diameter of the cyclone in respect of δ. Overflow size distribution is a simple function of the diameter of the apex orifice. Distribution of solids between underflow and overflow is a function of the ratio between the areas of vortex finder and apex orifice, and either of these may be modulated for the purpose of regulation, other conditions being held steady.

The advantages which have led to the widespread adoption of cyclones in Rand practice are, according to Krebs:

1. Sharper classification.
2. Saving of floor space.
3. Less power consumption.
4. Less maintenance.
5. Ability to shut down the mill immediately under full load.
6. Ability to bring the circuit rapidly into balance.
7. Elimination of cyclic surging.

In addition, operators of flotation plants claim operating benefits due to the higher percentage of solids in the overflow, and reduced dwelling time in the closed circuit. This latter consideration will be better understood when the effect of oxygen on newly sheared surfaces has been considered.

The cyclone is increasingly used for classification in the finer grinding ranges, between 150μ and 5μ, although coarser separations are possible. Separating efficiency is measurable as the percentage of misplaced product in either the overflow or underflow. Confusion can arise in assessing operating efficiency if the apex discharge is not under proper control. With a sprayed discharge the issuing solids should not exceed some 70% by weight of the total amount leaving at the apex. It is sometimes set to give a thick underflow carrying a higher percentage of solids. This means that the cyclone is overloaded and that some oversized material is unable to report with the apex discharge, and consequently is overflowed with the finer fraction. The correct adjustment can be made by varying the diameter of the apex discharge. This can be automated by pneumatic or hydraulic adjustment of the apex, signals being initiated in the vortex chamber or feed zone.

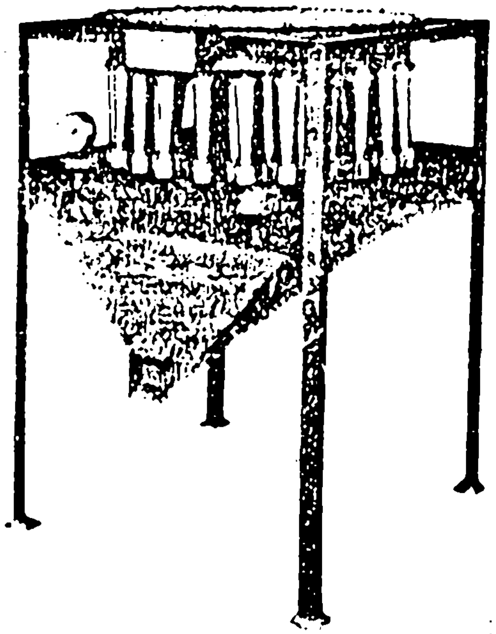

Fig. 97. *Multi Cyclone* (Liquid-Solid Separations)

The cyclone does not act as an effective substitute for the thickener in dealing with material below about 5μ in size. It can, however, concentrate the feed to a thickener or, alternatively, remove the bulk of the solids in the underflow. The overflow then carries a relatively small percentage of the finest solids, and can be led to any convenient settling area for further thickening. The tonnage of solids deposited in the re-thickening of the cyclone overflow would be too small to present serious handling difficulties.

An assembly of cyclones fed from a central distributing point is illustrated in Fig. 97. A testing unit for laboratory use is shown in Fig. 98, and a large cyclone in Fig. 99.

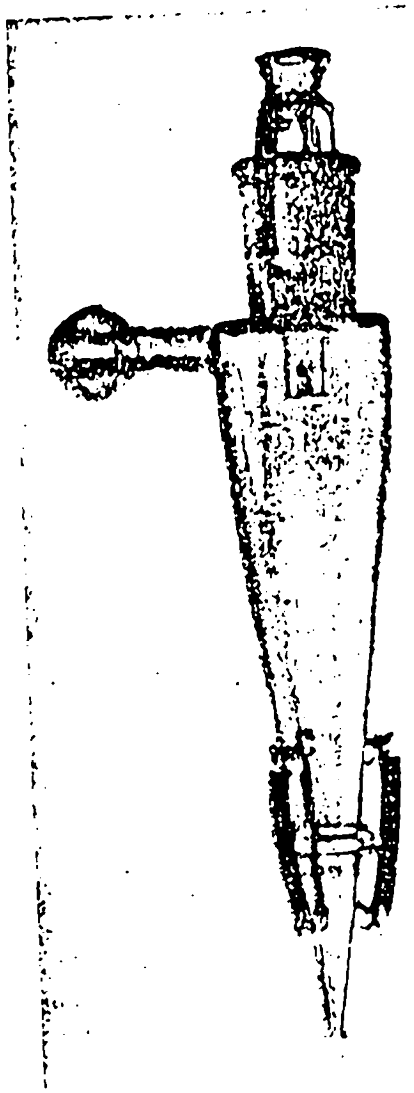

Fig. 98. Pyrex Hydrocyclone (Liquid-Solid Separations)

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When classification of much finer material is needed, mechanical spinning of the separating vessel can be used as in the Dynocone (Fig. 100). This consists of the conical revolving shell in which a screw conveyor rotates at a slightly higher speed. The solids settling to the inner wall of the cyclone are

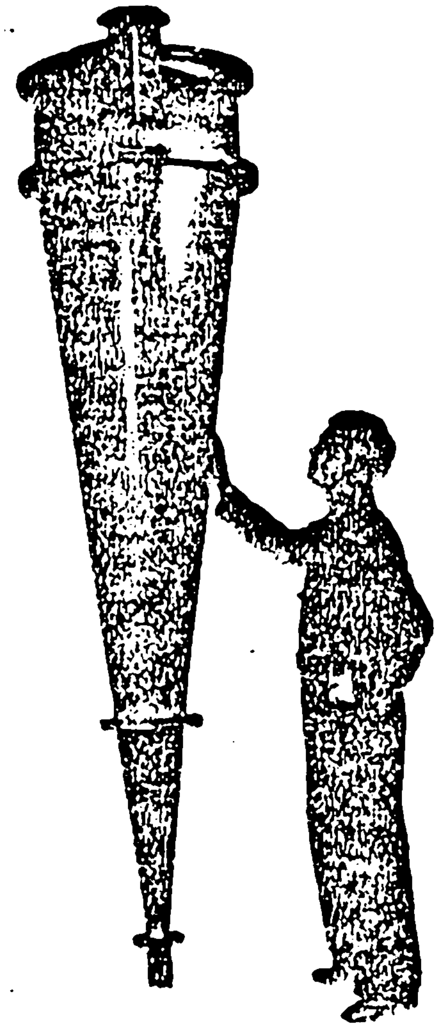

Fig. 99. Rubber-Lined Hydrocyclone (Liquid-Solid Separations)

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discharged by means of the screw, while the finer fraction overflows at the other end.

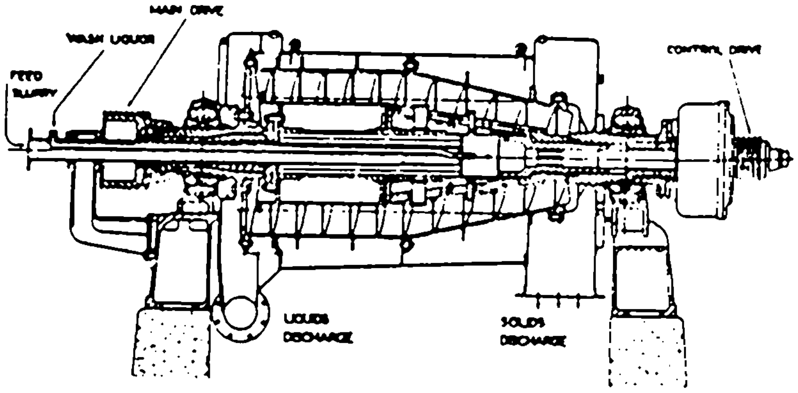

Fig. 100. *Section through Dynocone Centrifugal Classifier*
(International Combustion)

Air Sizing and Dust Control

When a particle is in movement in a liquid, part of its kinetic energy is expended in overcoming the viscosity, or molecular adhesion, of that liquid. If it moves through the liquid quickly enough to generate vortices, a substantial transfer of kinetic energy must occur in order to give these vortices sufficient power to thrust their way outward from the particle and maintain a temporary existence. When a particle moves through a gentle current of air viscous resistance is negligible. The only effective resistance encountered by the moving particle is the pressure-effect due to collision with gas molecules, which is a function (*a*) of the cross-section of the particle and (*b*) of its speed of motion relative to the air. Where the number of particles in a given volume is low, collision between these particles is negligible and they are "free-settling". As the crowding increases, collision multiplies and a change in settlement behaviour occurs. The interested reader will find mathematical treatment of the subject in Taggart[18] and Dallavalle.[19] Air is used for classification in dry grinding, and air currents are also so manipulated as to collect dust and aid in its deposition in suitable containers. In the first of these two cases, a split is made between larger and smaller particles as part of ore preparation. In the second, all possible dust is removed from the air in order to mitigate an industrial nuisance.

When air is the selective fluid in a sorting operation, reliance is placed on the use of an equable current of air, moving with as little unplanned turbulence as possible. If the air stream is vertical, the particle is either carried up or down as an elutriation. If it is horizontal, particles entering at one point fall out of the stream in accordance with their mass (or the time they take to fall through the stream) (Fig. 101).

The largest of the three spheres starting from rest at the point marked by an arrow falls fastest. It is therefore exposed for the shortest period to the displacing effect of the horizontal air stream. The smallest drifts the furthest under the same conditions.

The sheltering, and the frictional drag upon air and particles touching the containing walls of a vertical vessel, is sufficiently pronounced to require special precautions. Build-up of particles on these containing walls may occur, and machines used in air sizing and dust control sometimes contain devices for preventing this from becoming serious. Friction in a dry atmosphere causes electrostatic forces to be generated upon the particles, and aids their adhesion to one another and to the walls of the vessel. Apart from effects of this kind, the physical characteristics which determine how a given particle will behave in an air stream are its size, shape, density, and liability to collide with other particles (dispersion or concentration). The effects produced by the air stream depend on its velocity, humidity, viscosity (a pressure effect), and the way in which it is constrained to move by the containing walls of the appliance in which it operates. The settling velocity of a particle in still air is quoted by Taggart for irregular grains of S.G. 2·5 as 3140 ft./min. for 5000μ particles; 470 ft./min. for 500μ; 50 ft./min. for 24μ and 0·5 ft./min. for 0·0032μ or 3·2mμ.

If the velocity of the transporting stream of air is suitably controlled, relatively coarse particles are dropped while finer ones are carried onward. Baffles and deflecters may be placed in the stream to sort out the coarse particles in accordance with their inertia. In the cyclone a centrifugal sorting action is set up, the dust finding its way to the sides and then falling down while a vortex of comparatively dust-free air rises at the centre. The air is usually moved by a fan, working either to push a clean column of air forward or to draw dusty air through the system. To avoid wear of the blades, fan-power should be applied to clean air, or, alternatively, after the coarse particles have been trapped. A modified form of air classifier—the "gravitational-inertial"—for removing *minus* 100 mesh material from crushed limestone has been developed.[30] (Fig. 102.)

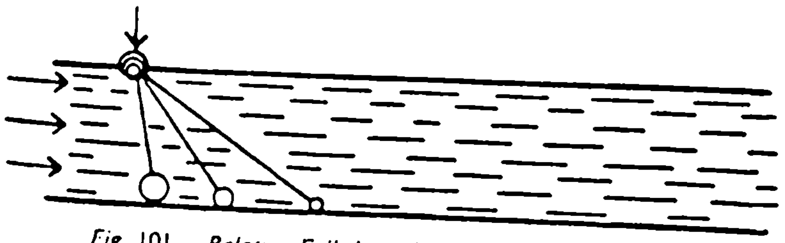

Fig. 101. *Relative Fall through a Horizontal Air Stream*

Despite the application of centrifugal force, the finest particles of dust cannot be trapped in a cyclone. Such dust might be a menace to the health of the workers. Various methods are used to minimise this risk. Cyclones can be used to remove dust coarser than 5μ. Parts of the mill operations which set up contamination should be enclosed and kept under a slight vacuum, so that dusty air does not leak out.

Electronic dust precipitation is used industrially to deal with particles too fine to settle by gravity. When a wire of small diameter receives a high charge of electricity a corona of gas molecules forms around it and these molecules collide and ionise. The ionised molecules can then be attracted toward a near-by grounded conductor. As they migrate they charge any passing dust particles they may collide with, and influence them to travel toward the grounded electrode. Dust can also be precipitated by passing it through a duct in which supersonic waves are vibrating at a sufficient intensity to cause the particles to flocculate into rapidly settling clots.

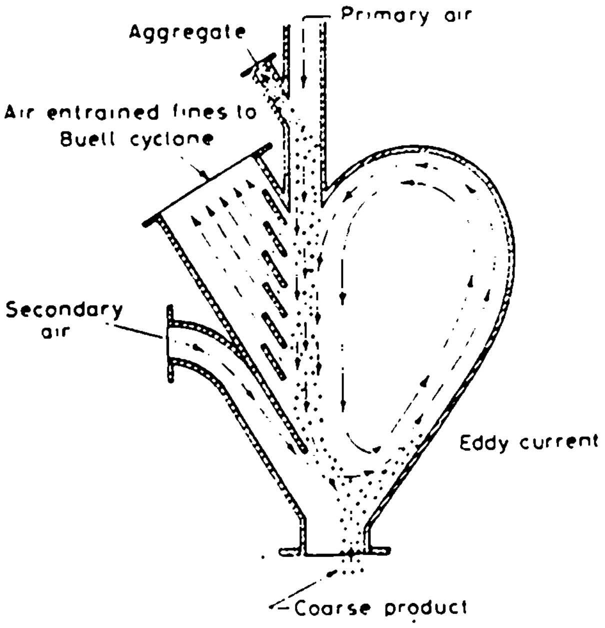

Fig. 102. The Gravitational Inertial Classifier

Closed Circuit Concentration

If two particles of the same shape and size, but of different specific gravities, are fed into a mechanical classifier, the heavier one may sink and be returned for further grinding while the lighter one overflows at the weir. Under such circumstances the mechanical classifier becomes a concentrating machine. This possibility was noted above when classifiers were referred to as sorting devices, not sizers. It is often undesirable that particles should remain in

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the closed circuit in this way. A metallic sulphide, once properly liberated, can be caught in the concentrating section of the plant more efficiently when it is still somewhat coarse than after it has been ground to an impalpable slime. A particle of free gold is usually malleable and merely changes its shape as the result of further passages through the mill. When necessary, effects of this kind are partially countered by the introduction into the closed circuit of a moderately efficient concentrating device appropriate to the working conditions. This is used to remove as much as possible of the desired value in the form of a rough concentrate, in order to minimise its over-grinding or accumulation in the closed circuit. Such appliances are colloquially termed "scalpers". Jigs, flotation cells, hydraulic classifiers, and corduroy strakes are among the devices used for this purpose.

Classifiers v. Cyclones

The closed circuit in wet grinding is rarely controlled by screening. The choice lies principally between mechanical classifiers and cyclones, though flow-sheets using gravity processes of concentration may have hydraulic classifiers for reasons which are discussed in Chapter 14. The growth in use of the cyclone has been rapid during the past few years, and data for adequate comparison with the older appliances are still inadequate. The mechanical classifier has the advantages over its rivals of tolerating and smoothing out surges, of returning its oversize to the mill launder without need for an extra machine, of being robust, long wearing, and easy to control. The screen fails because it cannot handle fine sand efficiently, and is therefore unsuitable for liberation of most of the low-grade and fine-grained ores which are treated today. Use of the cyclone owes its phenomenal growth to several facts. First, by its use of centrifugal force it can speed up settlement rate and therefore either handle larger tonnages with light equipment in a small space, or make a separation at finer meshes than can the classifier. Next, running costs are comparable but capital cost and installation are far cheaper. Third, by returning its oversize direct to the feed trunnion, it does away with the need for a scoop and feed box. Next, a point which specially affects flotation, it only keeps a small tonnage in circulation and hence reduces oxidising effects in the grinding circuit. Last, the limitation in fine grinding when the circuit is closed by a bowl classifier is that only a moderate circulating load is possible, the limit being dictated by the free-settling speed of the near-release particles. Using the accelerated settlement due to centrifugal force the cyclone makes possible a large circulating load. Repeated passage through the secondary mill, as with the primary one, lessens over-grinding.

Classifier Efficiency

This is checked by making screen analyses of properly collected samples of (*a*) material entering the classifier, (*b*) coarse discharge, (*c*) fine discharge.

These sizing analyses, plotted as "direct" graphs, should show a marked peak at the desired mesh of maximum separation, while the relation of the undersize and oversize to this peak mesh is a guide to behaviour in the circuit under the conditions ruling when the sample is taken. If operating changes are called for, they must be made one at a time, empirically. It must be remembered when judging efficiency that each change made anywhere in the closed circuit affects the whole circuit. Classifier efficiency cannot safely be considered in isolation from the conditions in the grinding mill and/or concentrator.

The control used by the shiftsman during the hour-by-hour running of the wet-grinding closed circuit corrects the density of the overflowing pulp. Provided this pulp is truly representative of the conditions in the top few inches of the classifier pool and is not upset by the presence of an overrunning stream of diluting water, its two sorting components—pulp density and hydraulic transporting energy—exercise effective control over the mesh sizes in the overflow. The accurate control of pulp density is therefore a major factor in operating efficiency. Haultain[21] observes that most bowl classifiers are worked with a cyclic surge of between 15 min. and 30 min. duration, during which the pulp in the rake compartment rises anywhere up to 9" above the normal working level, while corresponding variations in the sorting action takes place.

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CHAPTER 8

INDUSTRIAL SCREENING

Introduction

Industrial sizing of materials is extensively used, and the types of equipment are many and varied. Screening is generally carried out on relatively coarse material, as the efficiency decreases rapidly with fineness. Fine screens are very fragile and expensive and tend to become blocked rather easily with retained particles ("blind"). Screening is generally limited to material above about 250 μm in size, finer sizing normally being undertaken by classification (Chapter 9), although the boundary between the two methods will in practice depend on many factors, such as the type of ore, the plant throughput, etc.

There is, of course, a wide range of purposes for screening. The main purposes in the minerals industry are:

(a) to prevent the entry of undersize into crushing machines, so increasing their capacity and efficiency;
(b) to prevent oversize material from passing to the next stage in closed-circuit fine crushing and grinding operations;
(c) to prepare a closely sized feed to certain gravity concentration processes;
(d) to produce a closely sized end product. This is important in quarrying, where the final product size is an important part of the specification.

Performance of Screens

In its simplest form, the screen is a surface having a multiplicity of apertures of given dimensions. Material of mixed size presented to that

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surface will either pass through or be retained, according to whether the particles are smaller or larger than the governing dimensions of the aperture. The efficiency of screening is determined by the degree of perfection of separation of the material into size fractions above or below the governing dimensions of the aperture.

There has been no universally accepted method of defining screen performance and a number of widely used methods are employed. The most common screen performance criteria are those which state an efficiency based on the recovery of material at a given size, or on the mass of misplaced material in each product. This immediately leads to a range of possibilities, such as undersize in the overscreen product, oversize in the through-screen product, or a combination of the two.

An efficiency equation can be calculated from a mass balance across a screen as follows:

Consider a screen (Fig. 8.1) on to which there is a feed of F t h^{-1}; C t h^{-1} overflows from the screen, and U t h^{-1} is the rate of underflow.

Let f be the fraction of material above the cut point size in the feed; c be the fraction of material above the cut point size in the overflow; and u be the fraction of material above the cut point size in the underflow. f, c, and u can be determined by sieving a representative sample of each of the fractions on a laboratory screen of the same aperture size as the industrial screen and assuming this to be 100% efficient.

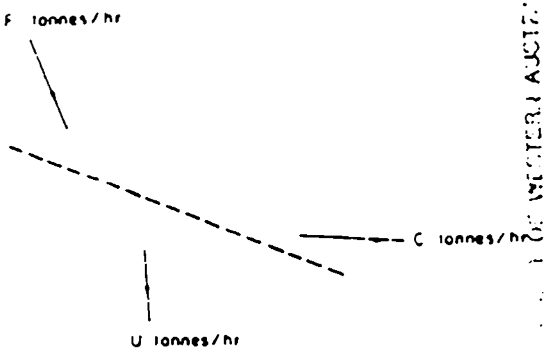

FIG. 8.1. Mass balance on a screen.

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The mass balance on the screen is

$$F = C + U.$$

The mass balance of the oversize material is

$$Ff = Cc + Uu$$

and the mass balance of the undersize material is

$$F(1-f) = C(1-c) + U(1-u).$$

Hence

$$\frac{C}{F} = \frac{f-u}{c-u}$$

and

$$\frac{U}{F} = \frac{c-f}{c-u}.$$

The recovery of oversize material into the screen overflow

$$= \frac{Cc}{Ff} = \frac{c(f-u)}{f(c-u)} \qquad (8.1)$$

and the corresponding recovery of undersize material in the screen underflow

$$= \frac{U(1-u)}{F(1-f)}$$

$$= \frac{(1-u)}{(1-f)}\frac{(c-f)}{(c-u)}. \qquad (8.2)$$

These two relationships, (8.1) and (8.2), measure the effectiveness of the screen in separating the coarse material from the underflow and the fine material from the overflow.

A combined effectiveness, or overall efficiency E is then obtained by multiplying the two equations together:

$$E = \frac{c(f-u)}{f(c-u)^2}\,\frac{(1-u)(c-f)}{(1-f)}. \qquad (8.3)$$

If there are no broken or deformed apertures, the amount of coarse material in the underflow is usually very low and a simplification of equation (8.3) can be obtained by assuming that it is, in fact, zero (i.e. $u = 0$), in which case the formula for fines recovery and that for the overall efficiency both reduce to

$$E = \frac{c - f}{c(1 - f)}. \tag{8.4}$$

This formula is widely used and implies that recovery of the coarse material in the overflow is 100%.[1]

Formulae such as the one derived are acceptable for assessing the efficiency of a screen under different conditions, operating on the *same feed*.

They do not, however, give an absolute value of the efficiency, as no allowance is made for the difficulty of the separation. A feed composed mainly of particles of a size near to that of the screen aperture —"near mesh" material—presents a more difficult separation than a feed composed mainly of very coarse and very fine particles with a screen aperture intermediate between them. For this reason, some efficiency criteria are based only on the near size material in the feed.[2]

In order to express screen and classifier performance on a unified basis, the Australian Standard, AS 1634-74, dealing with test result presentation, was introduced.[3]

It is closely modelled on the international standard of recommended methods for the presentation of the results of the performance of gravity classifiers, which is covered in Chapter 11.

The *partition curve* for the separation is drawn by plotting the partition coefficient, defined as the percentage feed of each fraction reporting to the oversize product, against the geometric mean size on a logarithmic scale. (For particles in the range, say, minus 125 plus 63 μm, the geometric mean size is $\sqrt{(125 \times 63)}$.) Figure 8.2 shows ideal and real partition curves.

The separation size is obtained at 50% probability, i.e. the size at which a particle has equal chance of reporting to the undersize or oversize product.

The efficiency of separation is assessed from the steepness of the curve. The sharpness of the separation is based on the 25, 50, and 75% partition coefficients and is defined as the ratio of sizes corresponding to 75 and 50% and 50 and 25% probabilities, respectively. As Adorjan observes,[4] this is an unfortunate choice, since perfect separation gives a partition error of

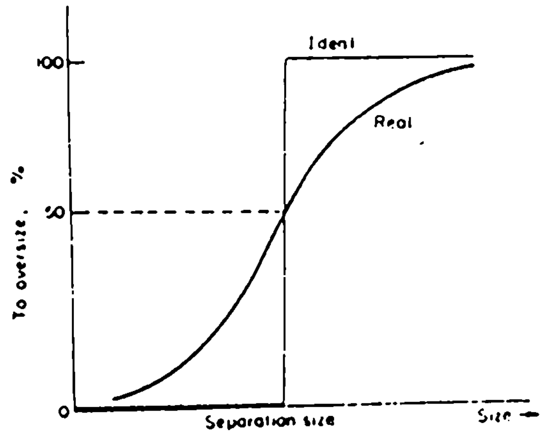

Fig. 8.2. Partition curve.

unity. A more meaningful measure would have been the fractional probable error of separation, i.e. the differences between sizes corresponding to 75 and 50% or 50 and 25% probabilities, expressed as a percentage of separation size. This would also allow comparison of screen or classifier performance at different sizes of separation, but would give nil partition error for a perfect separation.

Factors Affecting Screen Performance

Screen effectiveness must always be coupled with capacity as it is often possible by the use of a low feed-rate and a very long screening time to effect an almost complete separation. In practice economics dictates that relatively high feed-rates should be used, which reduces particle dwell time on the screen and often produces a thick bed of material through which the fines must travel to the screen surface. The net effect is reduced efficiency. High capacity and high efficiency are opposing requirements for any given separation, and a compromise is necessary to achieve the optimum result. At a given capacity, the effectiveness depends on the nature of the screening operation, i.e. on the overall chance of a particle passing through the screen once it has reached it.

The overall probability of passage of one particle is a product of the number of times that a particle strikes the screen and the probability of its passage through the screen during a single contact.[11]

As well as feed rate, an important factor dictating the number of strikes that a particle makes on the screen is the rate of vibration of the screen. Screens are vibrated in order to increase their efficiency, as blinding is reduced and segregation of the feed material is induced, which allows the fines to work through the layer of feed to the screen surface. Too high a vibration rate may, however, reduce the efficiency, as the particles may bounce from the screen wires and be thrown so far from the surface that there are very few strikes. Higher vibration rates can, in general, be used with higher feed-rates, as the deeper bed of material has a "cushioning" effect which inhibits particle bounce.

There are many factors affecting the chance of an individual passage through the screen once the particle has reached it. The angle of approach and particle orientation to the screen are important; the closer to the perpendicular is the angle of approach, the higher the chance of passage. If the particle shape is non-spherical, then some orientations will present a small cross-section for passage and some a large cross-section; mica, for instance, screens extremely badly, its flat, plate-like crystals tending to "ride" over the screen apertures.

The chance of passing through the aperture is proportional to the percentage of *open area* in the screen material, which is defined as the ratio of the net area of the apertures to the whole area of the screening surface. The smaller the area occupied by the screen material, the greater the chance of a particle reaching an aperture.

Open area decreases with the fineness of the aperture of screens with wires of the same diameter and in order to increase the open area of a fine screen, very thin wires must be used, which makes the screen fragile. This is the main reason for classifiers taking over from screens at fine aperture sizes. Due to the greater open area of coarse screens, the capacity is greater than that of fine screens and, in general, the maximum permissible rate of feeding is roughly proportional to the diameter of the apertures.

Probably the most important factor determining screen performance is the nature of the feed material. The efficiency is markedly reduced by the presence of particles close to the aperture size; these particles tend to "blind" the apertures, reducing the available open area and often report

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into the oversize fraction. This is often a problem with screens run in closed circuit with crushers, where a build up of "near mesh" material occurs which progressively reduces efficiency. Screens are often used in these cases which have apertures slightly greater than the set of the crusher, thus allowing this material to pass out into the screen undersize.

Taggart[5] gives some probabilities of passage related to the particle size, which are shown in Table 8.1. The figures relate the probable chance per thousand of unrestricted passage through a square aperture of a spherical particle and gives the probable number of apertures in series in the path of the particle necessary to ensure its passage through the screen. It can be seen that as the particle size approaches that of the aperture, the chance of passage falls off very rapidly.

The amount of moisture present in the feed has a marked effect on screening efficiency, as does the presence of clays and other sticky materials which should be removed early in the treatment route (Chapter 2). Damp feeds screen very poorly as they tend to agglomerate and blind the screen apertures. Screening must always be performed on perfectly dry, or wet, material, but never on damp material. If screening efficiency is the only criterion, then wet screening is always superior; finer sizes may be

TABLE 8.1. PROBABILITY OF PASSAGE

Ratio of particle to aperture size	Chance of passage per 1000	Number of apertures required in path
0.001	998	1
0.01	980	2
0.1	810	2
0.2	640	2
0.3	490	2
0.4	360	3
0.5	250	4
0.6	140	7
0.7	82	12
0.8	40	25
0.9	9.8	100
0.95	2.0	500
0.99	0.1	10^4
0.999	0.001	10^6

processed, adherent fines are washed off large particles, and the screen is cleaned by the flow of pulp. There is no dust problem. There is, however, the cost of dewatering and drying the products, and in many instances this is so high that dry screening, with its deficiencies, is preferred.

Screen Types

There are many different types of industrial screens[6], which may be classified as either stationary or moving screens.

Stationary Screens

The grizzly. Very coarse material is usually screened on a grizzly, which, in its simplest form, consists of a series of heavy parallel bars set in a frame. Some grizzlies employ chains instead of bars and some are shaken or vibrated mechanically to help the sizing and to aid in the removal of the oversize (Fig. 8.3). The most common use of grizzlies in mineral processing is for sizing the feed to primary crushers. If the primary crusher has a 10-cm product, then the feed is passed over a grizzly with a 10-cm spacing between the bars, in order to "scalp", or remove, the undersize.

The bars of a grizzly are inclined usually at an angle of between 20–50°, the greater the incline, the greater is the throughput, but the lower is the efficiency. Feed flows down the grizzly in the direction of the bars to assist flow and to reduce clogging. Clogging is a major problem, especially on the cross-members which hold the bars together. The bars are usually tapered in cross-section to minimise clogging once particles have entered between them.

The size of particle screened on grizzlies can be as large as 300 mm, or as small as 20 mm. The capacity, which can be up to $1000\,t\,h^{-1}$, is proportional to the area.

Sieve bends. Static screens, such as the Dutch State Mines (DSM) sieve bend, and its later version, the Dorr Rapifine, have gained wide acceptance in the minerals industry for very fine wet screening purposes.

The sieve bend (Fig. 8.4) has a curved screen composed of horizontal wedge bars. Feed slurry enters the upper surface of the screen tangentially and flows down the surface in a direction perpendicular to the openings

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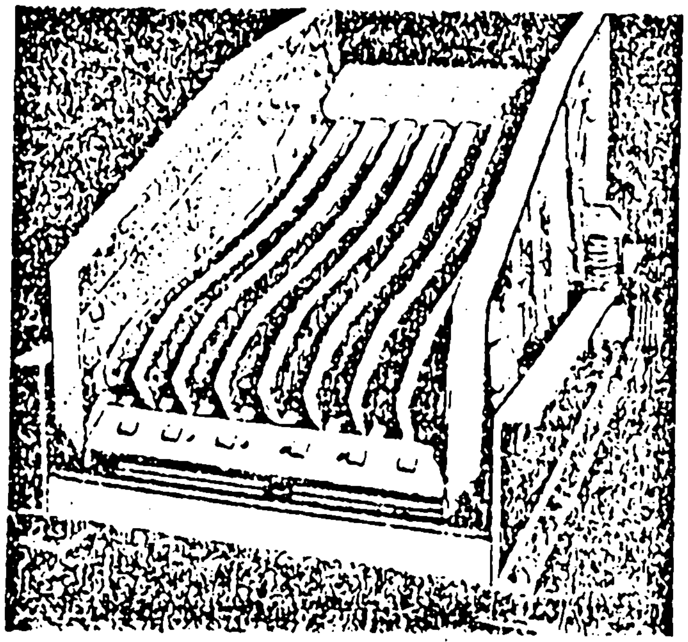

Fig. 8.3. Vibrating grizzly.

between the wedge bars. As the stream of slurry passes each opening a thin layer is peeled off and directed to the underside of the screen. According to Fontein,[7] particles roughly twice the thickness of this layer are dragged along with the undersize fraction; particles larger than this size pass across the openings as their greatest part projects into the liquid flowing over the slot. The thickness of the layer peeled off is primarily a function of the space between the bars, and investigation has shown that the thickness of this layer is in the order of 25% of the slot width.[8] In general, therefore a separation is produced at a size roughly equivalent to half the bar spacing and so very little plugging of the apertures should take place. Separation can be undertaken down to 50 μm and screen capacities are up to 180 $m^3 h^{-1}$ for every square metre of screen area and single units are built to handle 450 $m^3 h^{-1}$.

One of the problems associated with the DSM sieve bend is that whilst

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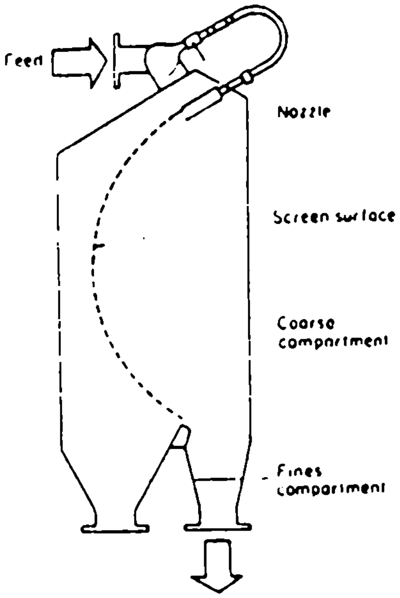

FIG. 8.4 Sieve bend.

separation occurs on the face of the screen, the thin layer of pulp, having passed through the apertures, tends to continue down the back (convex side) of the cloth, being held on by a "wall effect". The Dorr Rapifine incorporates a periodic rapping to the screen to dislodge adhering particles, while the Bartles CTS screen(9) has a series of crimps on the back of the cloth to divert pulp clinging to the back of the cloth. A later version uses a bonded plastic strip for this purpose. The unit has a primary stage, followed by a scavenging stage (Fig. 8.5), which has been found to produce a cleaner oversize product. The capacity, at a separation size of 150 μm, is about 26 $m^3 h^{-1}$ for 1-m width of screen.

Sieve bends have found an important application in closed-circuit grinding of heavy mineral ores. Overgrinding of the heavy minerals, which can occur when conventional classification is used, can be greatly reduced by the combination of classifiers and sieve bends.(10)

The Hukki screen (Fig. 8.6) employs a combination of classification and

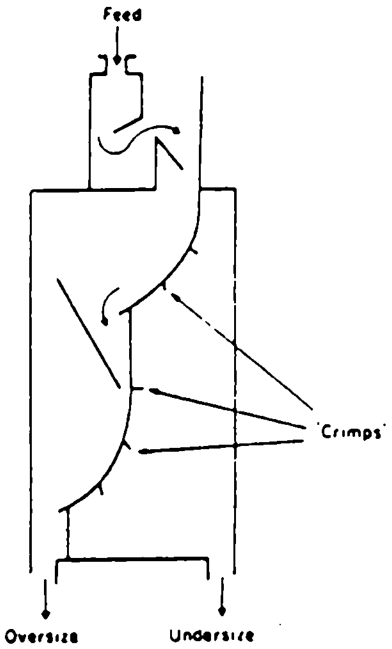

FIG. 8.5. Bartles CTS screen

screening and has been used in grinding circuits.[11] It consists of an open stationary vessel with a cylindrical top section and a conical base. The top section includes a cylindrical screen. Feed enters centrally at the top and is distributed inside the cylindrical screen by means of a low-speed rotating mechanism. Wash water is introduced into the conical section. The undersize passes through the cylindrical screen, which consists of wedge bars, into a collecting launder, whilst the oversize fraction is discharged through the apex.

Moving Screens

Revolving screens. One of the oldest screening devices is the *trommel* (Fig. 8.7), which is a slightly inclined, rotating cylindrical screen, which can be used wet or dry.

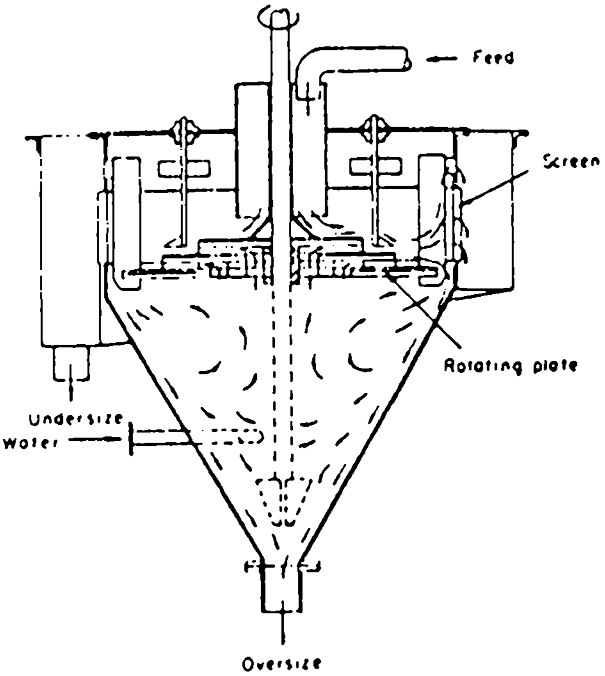

FIG. 8.6. Hukki screen.

Material is fed in at one end of the drum, undersize material passing through the screen apertures and the oversize material coming off at the opposite end.

Trommels, such as the one shown, can be made to deliver several sized products. The main problem is that the fine screen wears quickly, as the whole of the feed must be fed on to it.

Trommels may be arranged in series, with the coarsest discharging its undersize into consecutively finer trommels. This method, however, requires a great deal of floor space.

The problem of undue wear on the fine-screen trommel is overcome in 10 the *compound trommel* which has a series of concentric cylinders, with the coarsest screen at the centre, such that the coarsest fraction is removed first. It suffers from the disadvantage that failure of the inner screens is difficult to

Fig. 8.7. Trommel screen.

observe and they are difficult to replace when worn. It therefore has very limited use.

Trommels can handle material from 55 mm down to 6 mm, and even smaller sizes can be handled under wet screening conditions. They are widely used in the grading of sand and ballast and are still seen in a few ore-washing plants.

Although trommels are cheap, vibration-free, and robust, they have poor capacities since only part of the screen surface is in use at any one time and they "blind" very easily. They are tending to be replaced by one or other of the range of shaking or vibrating screens.

Shaking screens. Shaking screens have a reciprocating movement mechanically induced in the horizontal direction and are mounted either horizontally or with a gentle slope. They operate in the range of 60–800 strokes per minute, and find their greatest use as grading screens for relatively large sized feeds, down to about 12 mm. They are widely used dry in coal preparation, but find little use on abrasive metalliferous ores.

Reciprocating screens. Reciprocating screens employ a horizontal gyratory motion to the feed end of a rectangular screen by means of an unbalanced rotating shaft, rotating at about 1000 rev min^{-1}. The horizontal circular motion at the feed end gradually diminishes through the length of the machine to an elliptical movement, and finally to an approximate straight line reciprocating motion at the discharge end (Fig 8.8).

The circular motion at the feed end immediately spreads the material across the full width of the screen surface, even though it is fed from a single point. This horizontal circular motion also stratifies the material, causing the fines to sink down against the screen mesh. As the material travels along

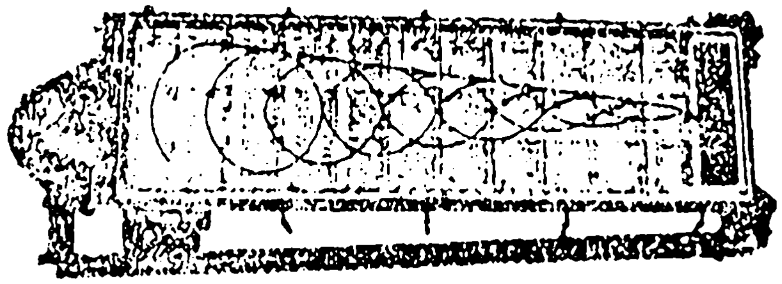

FIG. 8.8. Plan view of reciprocating screen.

the screen surface it enters the area of gradually diminishing screening motion at the discharge end. This reduced action aids the screening out of the "near mesh" particles. The screen is slightly inclined, and some commercial screens have ball trays below the screen; resilient balls confined in these trays are deflected against bevel strips by the machine motion and bounce continuously against the undersize of the screen mesh, thus reducing blinding.

These screens are used for fine separation, mainly dry, of light materials in the range 10 mm to 250 μm, and sometimes down to 40 μm.

Gyratory screens. This type of screen, which imparts gyratory motion throughout the whole screen cloth, is becoming widely used for fine-screening applications, wet or dry, down to 40 μm.(11) The basic components consist of a nest of sieves supported on a table which is mounted on springs on a base; suspended from beneath the table is a motor with double-shaft extensions, which drives eccentric weights and in doing so effects horizontal gyratory motion (Fig. 8.9). Vertical motion is imparted by the bottom weights, which swing the mobile mass about its centre of gravity, producing a circular tipping motion to the screen, the top weights producing the horizontal gyratory motion.

As in the reciprocating screen, ball trays may be fitted below a screen assembly to reduce blinding.

Figure 8.10 shows gyratory screens sizing zinc oxide in a Belgian plant.

Vibrating screens. Vibrating screens are the most important screening machines for mineral processing applications.(12,13) They handle material

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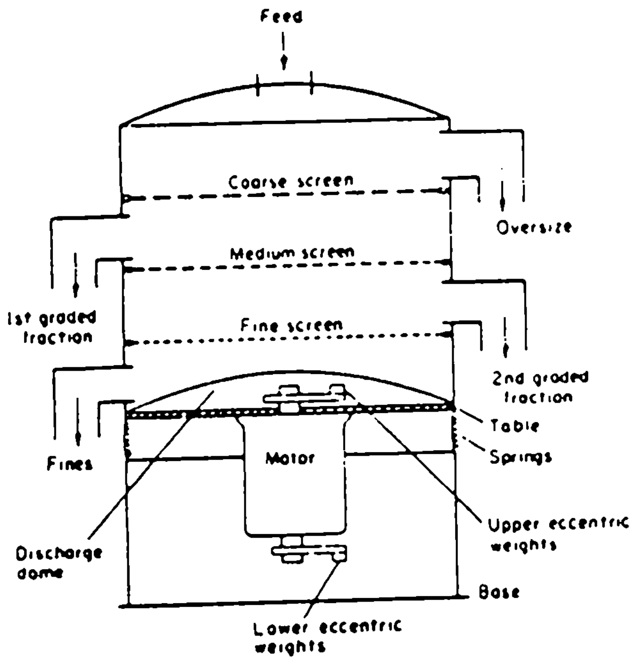

FIG. 8.9. Gyratory screen.

up to 25 cm in size down to 250 μm. Their main application is in crushing circuits where they are required to handle material ranging, in general, from 25 cm to 5 mm in size.

Vibration is induced vertically either by the rotation of a mechanical reciprocating device applied to the casing or by electrical devices operating directly on the screen.

They can work at low slopes and need little headroom. In multiple-deck systems the feed is introduced to the top coarse screen, the undersize falling through to the finer screens, thus producing a range of sized fractions (Fig. 8.11).

Electrically vibrated screens, such as the Hummer (Fig. 8.12), operate with a high-frequency motion of very small throw, created by a moving magnet activated by alternating current. The electromagnetic vibrator is mounted above and connected directly to the screening surface.

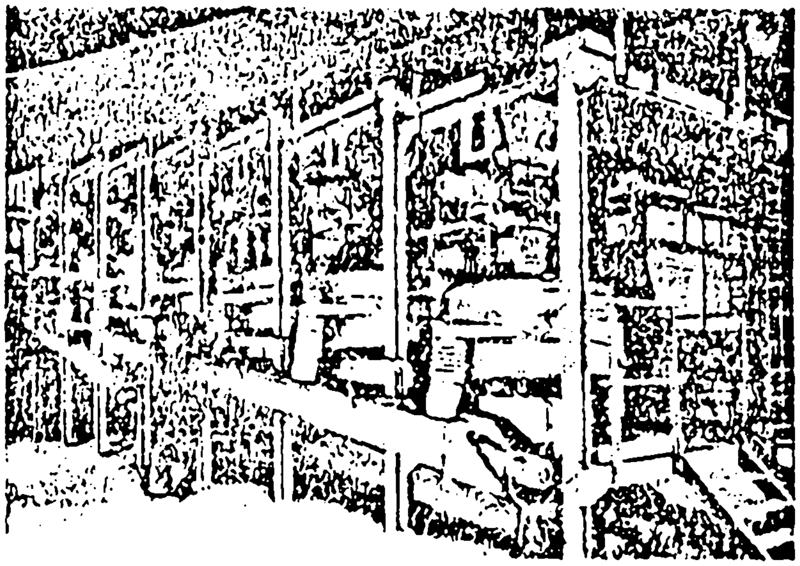

FIG. 8.10. Gyratory screens in operation

Electric screens are often used to dewater finely crushed ores, such as washing-plant classifier sands products (Chapter 2). For dry screening, they are limited to materials below about 12 mm in size.

The most widely used screens for coarser sizing are mechanically vibrated. There are two main methods of producing vibration. Eccentric motion is often preferred for feeds coarser than about 4 cm, while below this size, unbalanced pulleys are used.

Eccentric motion is imparted by a shaft, supported by a side-arm assembly, producing a circular throw. Figure 8.13 shows a typical assembly of one end of the shaft of a double-deck screen. The diagram shows the steel shaft (1); heavy-duty self-aligning roller bearings (2) with inner races pressed on the shaft, and outer races mounted in the cast steel housings (3); labyrinth seals (4) giving protection for the bearings by preventing grit from reaching them; counter-balanced fly-wheel (5), which, together with the

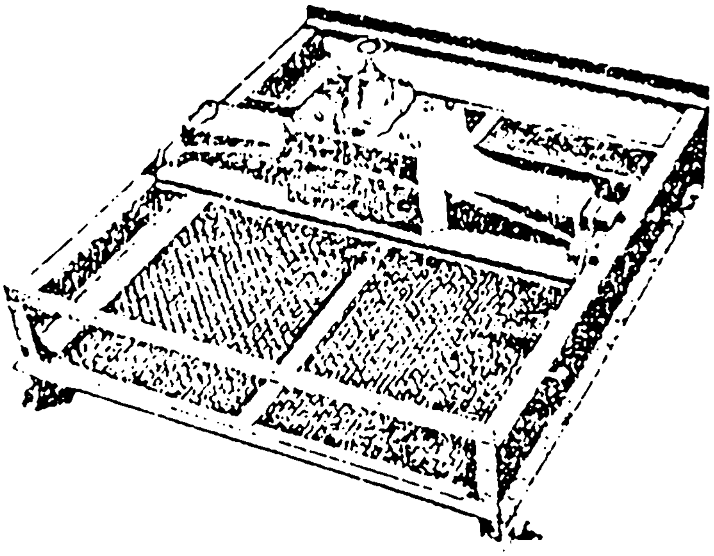

Fig. 8.12. Hummer screen.

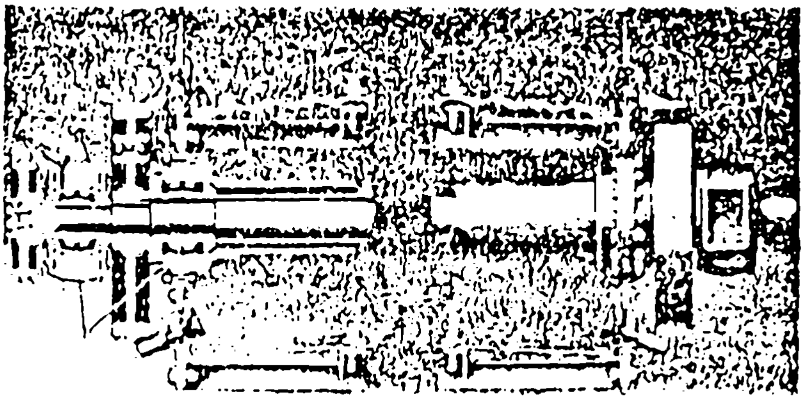

Fig. 8.13. Cross-section of eccentric shaft assembly

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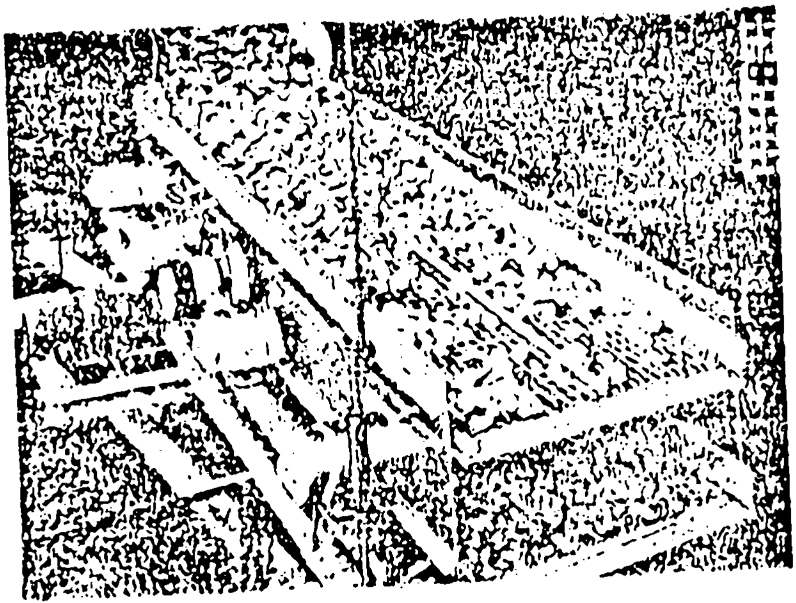

FIG. 8.11. Double-deck vibrating screen.

side-arm assembly, balances the screening body; side plates of the screening body (6); seamless steel-tube housing (7) with cast-steel tube heads assuring positive bearing alignment and accurate spacing between the side plates; packing strips (8) engaging the hook edges of the screen sections which are brought to tension by bolts passing through the side plate; cross-bracing panels (9) bolted permanently to the side plates to give rigidity to the screen.

Coarse-screening machines of the type shown in Fig. 8.11 are known as "full-floating screens", since the moving parts of the screen float entirely on rubber mountings, allowing absolute freedom to develop maximum screening action. This freedom allows the screen to adjust itself to varying load conditions so that the whole action is concentrated on the efficient separation of the material.

Vibration in the finer screening ranges is often produced by unbalanced weights or flywheels attached to the drive shaft. A typical unit is shown in Fig. 8.14. It consists of a heavy, machined, steel shaft running in double-row, ball-bearing, plummer blocks bolted direct to the screen main frame.

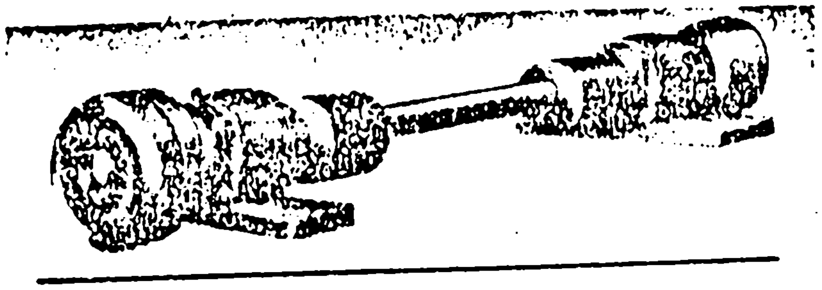

FIG. 8.14. Unbalanced-weight vibrating unit.

To the middle of the shaft are keyed two eccentric weights which, when rotating at correct speed, produce a smooth positive vibration, operating with equal intensity over the whole screen mesh.

In the system shown in Fig. 8.15 the shaft is balanced, but the flywheels at each end of the shaft are unbalanced. The shaft and bearings are entirely enclosed in a protective tube which is clamped in steel castings welded to the side of the screen box. The amplitude of throw can be adjusted by adding or removing weight elements bolted to the flywheels inside the rims. The vibrator cartridge unit is attached rigidly to the screen box and the entire assembly is mounted on involute springs of high strength and low 10

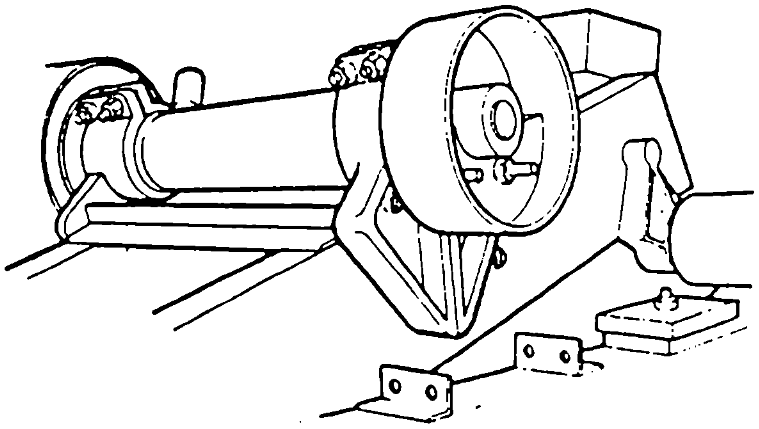

FIG. 8.15. Unbalanced-flywheel unit

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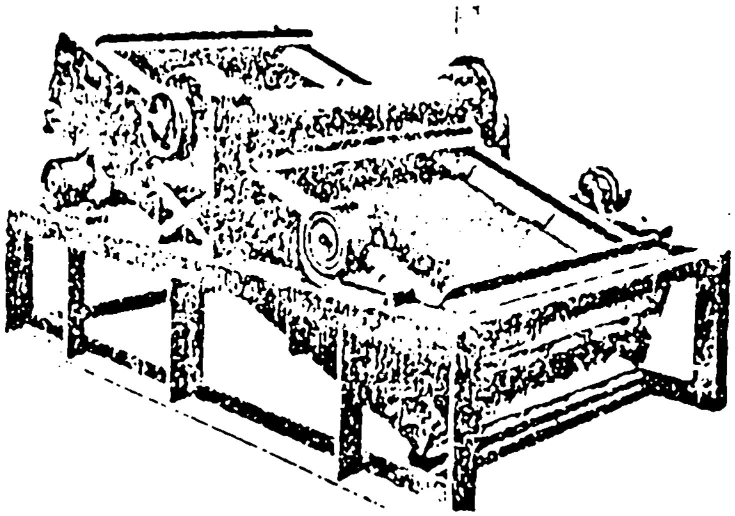

Fig. 8.16 Unbalanced-flywheel vibrating screen.

stiffness (Fig. 8.16). The vibrator generates an elliptical motion, slanting forward, at the feed end; a circular motion at the centre; and an elliptical motion, slanting backwards at the discharge end (Fig. 8.17). Forward motion at the feed end serves to move oversize material rapidly out of the feed zone to keep the bed as thin as possible. This action facilitates passage of fines which should be completely removed in the first one-third of the

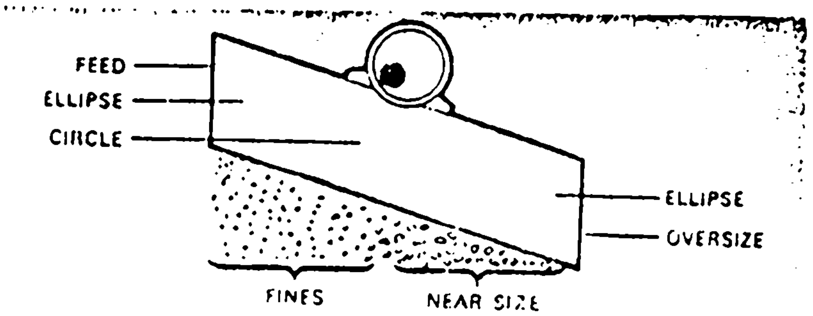

Fig. 8.17 Motion of vibrating screen

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screen length. As the oversize bed thins down, near the centre of the screen, the motion gradually changes to the circular pattern to slow down the rate of travel of the solid. At the discharge end, the oversize and remaining near-size materials are subjected to the increasingly retarding effect of the backward elliptical motion. This allows the near-size material more time to find openings in the screen cloth.

In most screens, energy is wasted in changing the direction of motion. In the *resonance screen* (Fig. 8.18) the screen frame is arranged so that it is freely vibrating between rubber buffers connected to a heavy weighted balancing frame, having a natural resonance frequency which is the same as that of the vibrating screen. Movement is imparted to the screen by an eccentric drive and the rubber buffers restrict the movement of the screen and store up energy, which is reimparted to the live frame. Any movement given to the screen is transmitted to the balancing frame which stands on rubber pads. The motion sets up resonance vibrations, which, instead of

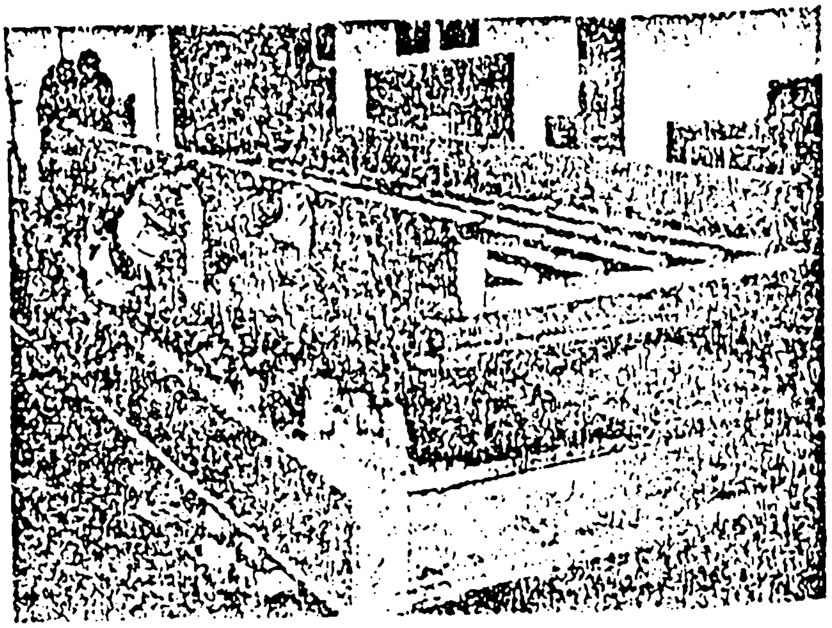

Fig. 8.18 Resonance screen.

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being wasted, are transmitted back to the screening frame, making energy losses minimal. In addition to storing energy, the sharp return motion of the deck produced by the buffers imparts a lively action to the deck and promotes good screening.

There are two main requirements which must be satisfied for efficient screening of fine materials. The first is the conveyance of particles to mesh apertures and their presentation in as many attitudes as possible. The second is to ensure that particles pass mesh apertures without blinding. In practice these are conflicting requirements, the former needing vibration frequencies around 20–50 Hz, while for prevention of blinding, frequencies of 10-30 kHz are necessary.(14) Several dual-frequency vibrating screens have been introduced which are claimed to produce higher efficiencies and throughputs.(15-17) The screens are vibrated by two motors, one mounted at the feed end and running at low speed and high amplitude, with the other at the discharge end running at high speed and low amplitude.

The Mogensen sizer operates on the principle that there is a definite and quantifiable probability that a particle will pass through an aperture larger than the maximum diameter of that particle.(18) In contrast to the conventional concept of screening, the material is allowed to fall freely through a system of oscillating and sloping screens all of which have a mesh size larger than the biggest particle to be treated (Fig. 8.19). The capacity is such that a particular screening duty can be met with a machine occupying a fraction of the floor space required by a conventional screen and blinding and wear is greatly reduced.

The *rotating probability screen* (Fig. 8.20), has been developed for extracting fines from damp raw coal of which, in recent years, there has been a general increase due mainly to the increased use of water sprays to meet more stringent underground dust regulations. This has caused considerable difficulty in separating fines by conventional means. Standard vibrating screens with woven wire-mesh apertures of 6 mm and below rapidly blind due to the build-up of damp fines, and developments in screen design, deck construction, and screening aids have had only limited success in overcoming this problem.

The rotating probability screen, developed by the NCB's Mining Research and Development Establishment, avoids the use of fine-aperture meshes and overcomes the problem of deck blinding.

It consists of a horizontal, circular screen deck mounted on a vertical

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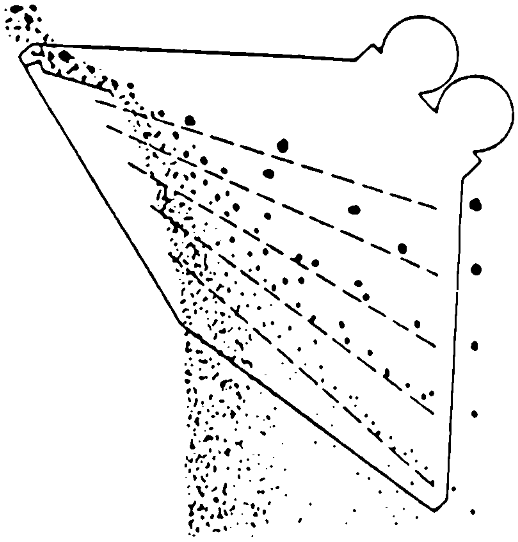

FIG. 8.19. Principle of Mogensen sizer.

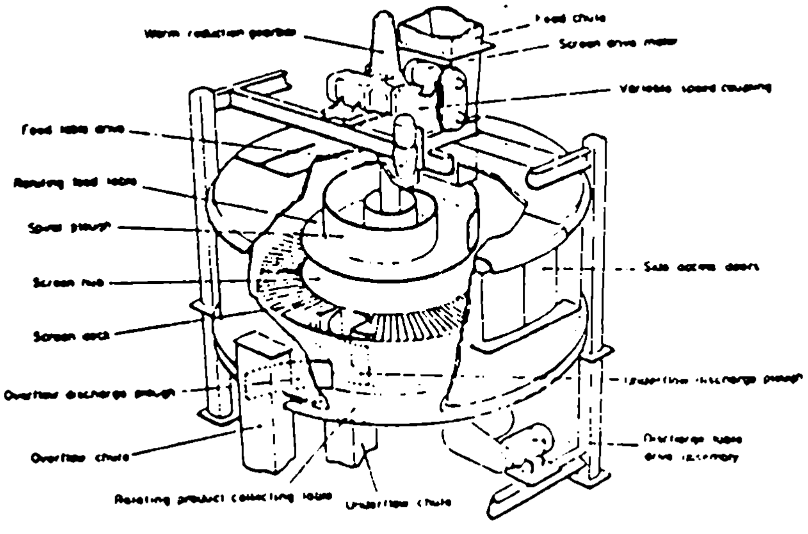

FIG. 8.20. Rotating probability screen.

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rotating shaft provided with a variable-speed drive. The screening surface is comprised entirely of small-diameter stainless steel rods radiating from a central hub. A uniform circular distribution of the feed material to the screen deck is achieved by a rotating feed table with a stationary spiral plough mounted above it.

The finer particles pass between the rotating rods while the coarser material is discharged around the periphery of the deck by centrifugal action. Both products are collected on a second rotating table, where they are kept separate by a cylindrical division and discharged by ploughs. The overall design of the screen is such that the material progresses either in free fall or by positive displacement over a smooth horizontal surface. The principle of its operation is based on the greater probability of the finer particles passing through the relatively large apertures between the rotating rods.

An important feature of the screen is that the effective screening size depends on the rotational speed which can be regulated either manually or automatically.

The main application is in situations where the ability to handle difficult, high-moisture material is of more practical importance than accurate size separation. Such is the case with dry fines extraction in coal treatment. The coarse fraction is usually treated by gravity separation to remove relatively heavy incombustible minerals and shales, while the fine fraction is eventually blended with the treated fraction to give a product of the required ash content. The screen provides a means of continuously controlling the amount of fines extracted according to the ash content of the raw coal, so that the treated and untreated constituents of blended coal can be made available in the required proportions. The capacity of a 2.4-m deck-diameter screen is around 100 t h^{-1} when handling minus 19-mm raw coal, and separating at about 4 mm.

Screening Surfaces

The type of screening surface chosen for a particular duty will depend on the aperture required and the nature of the work.

For very heavy-duty work, with the grizzly, parallel iron or steel bars or rails are set at a fixed distance apart.

Punched plate is used for many purposes. Heavy-duty "scalping" screens often use plate with circular or square holes. Punched plate with slotted openings is sometimes used for fine work.

Rod-deck screens are often used for heavy-duty work in the range 3-25 mm, especially in removing undersize from heavy tonnage crusher feeds in closed and open circuit. The tempered steel rods are sprung into place and are held firmly by moulded rubber spacers. The smaller-sized rods can be replaced individually by hand, while rods greater than 8 mm in diameter can be replaced by the aid of a tool supplied by the manufacturer.

Wedge wire screens are employed in many fine screening machines, such as sieve bends. Such screens are strong and have relatively large open areas. The wedge profile (Fig. 8.21) minimises particle blinding.

Woven-wire cloths, usually constructed from steel, stainless steel, copper, or bronze, are by far the most widely used screening surfaces, especially in the range encountered in crushing circuits. Various shapes of aperture and types of weave are available, although square mesh is usually used for fairly coarse screening and rectangular for fine screening. Rectangular screen apertures have a greater open area than square-mesh screens of the same wire diameter. The wire diameter chosen depends on the nature of the work

FIG. 8.21. Wedge wire screen

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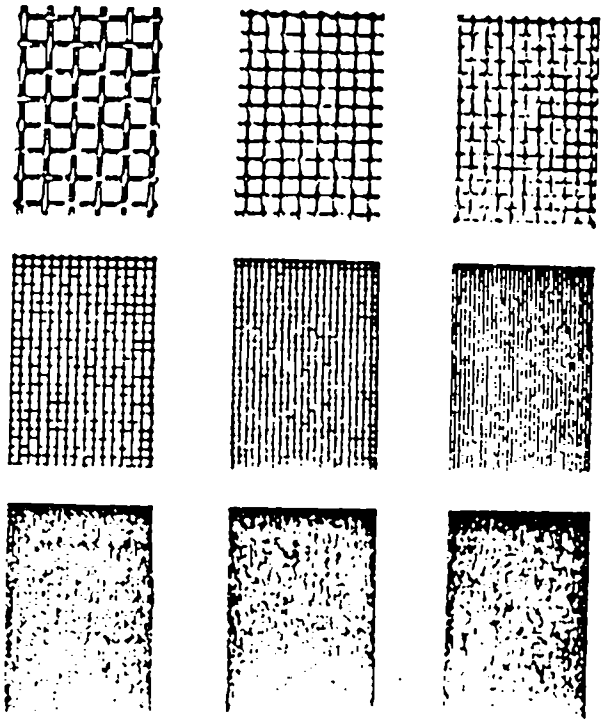

Fig. 8.22. Woven-wire cloth of different apertures but similar open area.

and the capacity required. Fine screens can have the same or greater open areas than coarse screens, but the wires used must be thinner and hence more fragile (Fig. 8.22).

Increasing the wire thickness increases their strength, but decreases open area and hence capacity.

Rectangular aperture screen cloths should be used with the long side of the mesh set across the flow for maximum capacity. They are often used on material that tends to "flake" into long thin fragments.

Various non-metallic screen surfaces, which greatly increase screen life due to reduced wear, are now used. Polyurethane rubber offers exceptional resistance to abrasion and impact, while effectively reducing noise, and is lighter in weight than wire cloth.(19) It offers more open area than other

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non-metallic screens and is manufactured with tapered holes, wider at the bottom than the top, to reduce blinding. Renison Ltd., Tasmania, replaced the stainless steel wedge wire screens of their primary grinding circuit with polyurethane wedge-bar screen panels and found that the efficiency was significantly better, and the screen life about five times greater than before.(10)

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EXHIBIT "19" Affidavit of Desmond Evered Wright dated 30.5.1983

IN THE SUPREME COURT
OF WESTERN AUSTRALIA

No. 2313 of 1982

IN THE MATTER of an Agreement between LANGLEY GEORGE HANCOCK, ERNEST ARCHIBALD MAYNARD WRIGHT, WRIGHT PROSPECTING PTY. LTD., HANCOCK PROSPECTING PTY. LTD, two other companies and HAMERSLEY IRON PTY. LIMITED

BETWEEN:

HAMERSLEY IRON PTY. LIMITED	Plaintiff
AND	
LANGLEY GEORGE HANCOCK	First Defendant
ERNEST ARCHIBALD MAYNARD WRIGHT	Second Defendant
HANCOCK PROSPECTING PTY. LTD.	Third Defendant
WRIGHT PROSPECTING PTY. LTD.	Fourth Defendant
L.S.P. PTY. LTD.	Fifth Defendant
THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED	Sixth Defendant

AFFIDAVIT

I, DESMOND EVERED WRIGHT of 26 Collier Street, Applecross in the State of Western Australia, Mining Engineer, make oath and say as follows:

1. (a) I hold the degrees of Bachelor of Science (Mining)(1942) and Bachelor of Science (Mining Geology)(1947) from the Royal School of Mines, London, and I am an Associate of the Royal School of Mines. I was a Member of the Institute of Mining and Metallurgy, London between 1938 and 1962, when I moved to Australia, and I was a Member of the Society of Mining Engineers of the American Institute of Mining Engineering until my retirement from full-time work in 1980.

EXHIBIT "19" Affidavit of Desmond Evered Wright dated 30.5.1983

"R.F. Baldock" "D.E. Wright"

(b) For three years from 1947 to 1950 I was Section Foreman at the Cerro de Pasco copper, lead and zinc mine at Morococha in Peru, overseeing and directing underground mining operations.

(c) From 1951 to 1954 I was employed as a Mining Engineer at Bethlehem Chile's iron ore mine at El Tofo in Chile's Coquimbo Province, supervising all aspects of mining and exploration. In 1954 I joined the Iron Mines Company of Venezuela and worked at that company's El Pao iron ore mine in Bolivar State, Venezuela as Chief Mining Engineer. In this capacity, I was responsible for mine planning and operations. In 1960 I moved to San Juan, Peru to take the position of Operating Assistant to the General Manager at Marcona Mining Company's iron ore mine. All these mines were open cut operations and all had crushing and screening facilities comparable to those used in the Pilbara and were concerned with the production and shipping of sized ore. Whilst I was employed with the Marcona Mining Company, a wet concentration facility was installed at San Juan Mine for beneficiating fine ore.

(d) From 1962 to 1963 I was Manager, Development with the Mt. Goldsworthy Mining Associates Joint Venture, in which capacity I was responsible for exploration, ore body assessment and feasibility studies. In 1964 I joined the Mt. Newman Joint Venture and worked for them until 1980. From 1964 to 1966 I was jointly responsible for the carrying out of feasibility studies for the construction of the Mt. Newman project, including the mine, railroad, port and township. Between 1966 and 1968 I was Chief Mining Engineer, in which capacity I was in charge of the development of the mine and associated plant. In 1968 I was made Manager, Development and in that role I was responsible for exploration, product quality control, shipping, customer relationships and planning. It was essential to have a thorough technical understanding of the function and interdependence of the various components of the project as well as of the uses and capabilities of mineral dressing processes generally. One part of my responsibilities was to oversee the development of metallurgical flow sheets for the Mt. Newman concentrator. I retired from Mt. Newman in 1980. In my thirty years in the iron ore industry I have visited numerous iron ore mines in Canada, the United States and

"R.F. Baldock" "D E Wright"

EXHIBIT "19" Affidavit of Desmond Evered Wright dated 30.5.1983

South Africa as well as in South America and Australia.

2. I have been asked to advise the Plaintiff in relation to these proceedings and I have read and ask leave to refer to the Affidavit of Colin Roy Langridge sworn on 2nd September, 1982 the Affidavits of Niles Earl Grosvenor and Peter Forbes Booth both sworn on 27th October, 1982, the Affidavit of Alban Jude Lynch sworn on 22nd May, 1983, the Affidavit of Arthur Noel Pritchard sworn on 24th May, 1983, the Affidavit of Douglas Frederick Tompsitt sworn on 24th May, 1983 and the Affidavit of Robin John Batterham sworn on 25th May, 1983 all filed herein. I have also examined the exhibits to each of those Affidavits, including the Agreement which is "Exhibit CRL 1". I inspected the Plaintiff's facilities at Tom Price in March, 1983.

3. I agree with the opinions expressed by Dr. Lynch in paragraphs 9 and 10 of his Affidavit and with the reasons he gives for them. I also agree with paragraphs 5, 6, 7 and 8 of Mr. Pritchard's Affidavit and paragraphs 5, 8 and 9 of Dr. Batterham's Affidavit. In my experience in the iron ore industry, water has never been added to a screening process unless it was designed to achieve a different result from what could be achieved by screening alone. As Mr. Pritchard states, water is a complicating and (especially in Australia) an expensive component and, in my experience, has not been used solely as an adjunct to crushing and screening without some further process in view.

SWORN by the said DESMOND)
EVERED WRIGHT at Midland)
in the State of Western Australia)
this 30th day of May)
1983.)

"D.E. Wright"

Before me:

SUPREME COURT WESTERN AUSTRALIA

"R.F. Baldock"

A Justice of the Peace

Filed on behalf of the Plaintiff.

EXHIBIT "19" Affidavit of Desmond Evered Wright dated 30.5.1983

Hamersley
20
23/3/82

Hancock
Ahlers
Booth
AB

Mt.Newman Mining

BENEFICIATION PLANT

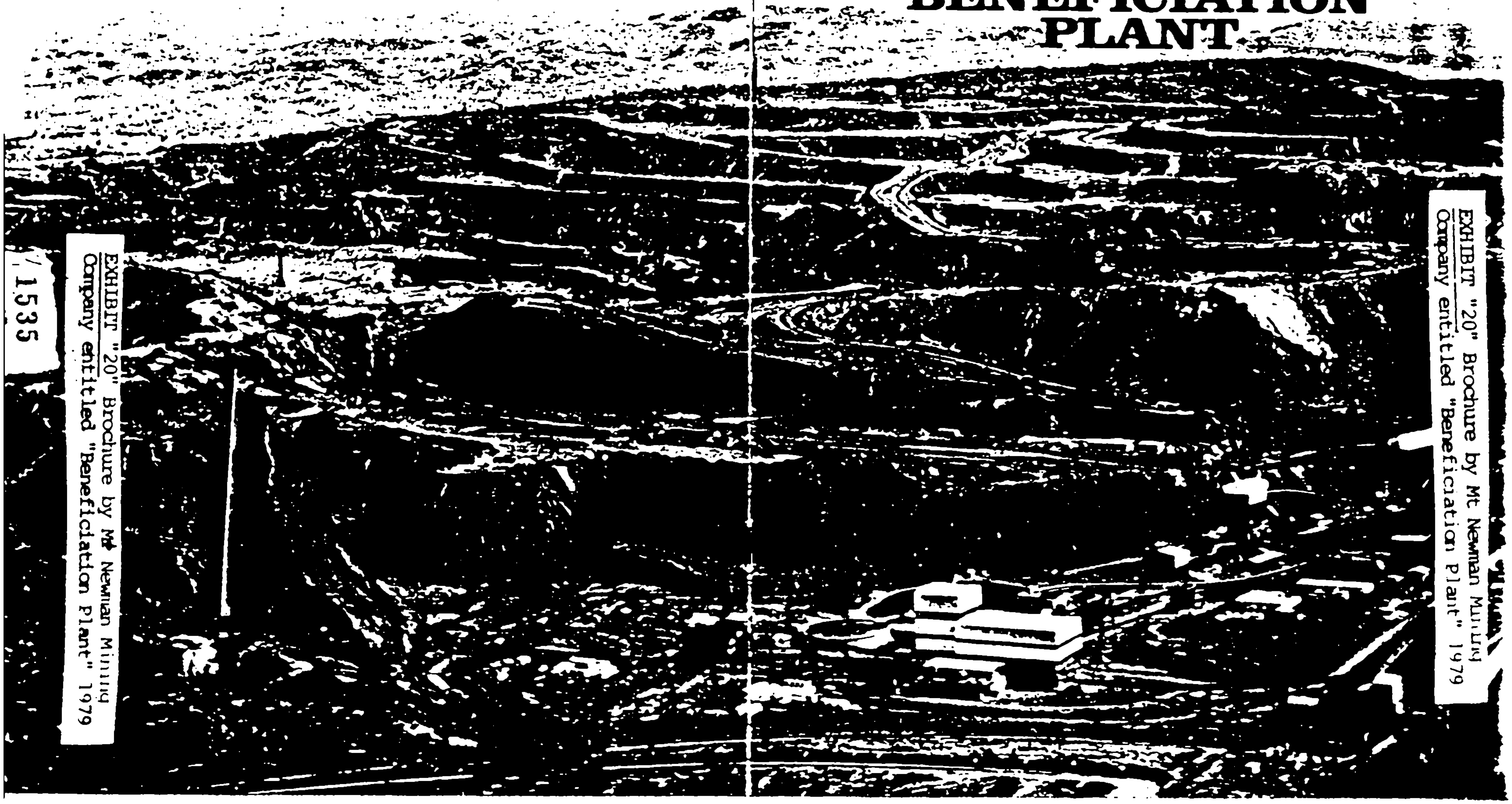

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

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Introduction

The Mt. Newman Beneficiation Plant Project was officially opened on June 26 1979 – coinciding with the celebrations marking 10 years of operation of the Mt. Whaleback open-cut iron ore mine.

The Plant was designed to produce 5.2M tonnes of ore, averaging 63 6% Fe, from 6.8M tonnes of beneficiable waste material averaging 55% Fe.

Built at a total cost of $A85M, the Project includes Ore Handling Plant No. 3, the Concentrator, Power Station Extension, major extension to the water supply, construction of 46 houses, and ancillary facilities.

Constructed three months ahead of schedule, it represents a new era of technology in the Pilbara Region of Western Australia.

The Joint Venture

Mt. Newman Mining Co. Pty Limited, a wholly owned subsidiary of Broken Hill Proprietary Co. Limited, manages the Mt. Newman Iron Ore Project, which is an enterprise in which Australian interests have a 60% holding.
Members of the Mt. Newman Joint Venture are:

AMAX Iron Ore Corporation, a subsidiary of AMAX Inc (25%)
Pilbara Iron Limited, a subsidiary of C.S.R. Limited. (30%)
Dampier Mining Co. Limited, a subsidiary of The Broken Hill Proprietary Co Limited. (30%)
Seltrust Iron Ore Limited, a subsidiary of Selection Trust Limited. (5%)
Mitsui-C. Itoh Iron Pty. Limited. (10%)

Mt. Newman, which started mining operations in January, 1969, holds contracts for the supply of high-grade iron ore to major steel mills in Australia and overseas. The Mt. Whaleback mine at Newman is the largest single iron ore mine in the world.

Secondary Processing

The original feasibility study for mining the Mt. Whaleback ore body showed that it had vast industrial potential. The guidelines for the venture were established in the "Iron Ore (Mount Newman) Agreement Act, 1964-67," which sets out the responsibilities of the Western Australian Government and of the Joint Venture in developing the vast operation.

One of the Joint Venture's commitments was that it should submit to the Government, before the end of Ore Year 10 (March, 1979) detailed proposals for a plant for the secondary processing of iron ore. This plant was to process 0.5 million tons of ore by the beginning of Ore Year 13 (April, 1981) and expand progressively to be able to treat 2.0M tons of ore during Ore Year 17, with an initial expenditure of not less than $A16M.

During 1976 and early 1977, serious consideration was given to embarking on this development ahead of the statutory requirement. Testing of the ore to be used in secondary processing was carried out and a detailed survey was made of the amount of beneficiable material available and its location.

To maintain grade targets when mining on Mt Whaleback, large tonnages of medium and low-grade ores, which are a mixture of high-grade hematite and shale, are produced in the general course of mining but cannot be utilised as part of the overall blend. This mixture, which occurs in mining of the contact between high-grade ore and adjacent waste material, is called contact ore and provides the feed to the Beneficiation Plant. Processing of this material will increase the proven reserves of Mt. Whaleback by about 145 million tonnes of high grade ore.

Design and Construction

Design of the Plant started in January, 1977 By August, 1977, the general arrangement drawings had been prepared for approval. During this time, test work and the final metallurgical flow diagrams were completed and approved.

The Western Australian Government approved the Secondary Processing submission and the Project received the "Go Ahead" in November, 1977 Construction began immediately. In one of the fastest and safest construction programmes yet undertaken by Mt Newman, the Plant was completed ahead of schedule and was working in May, 1979

The Beneficiation Process

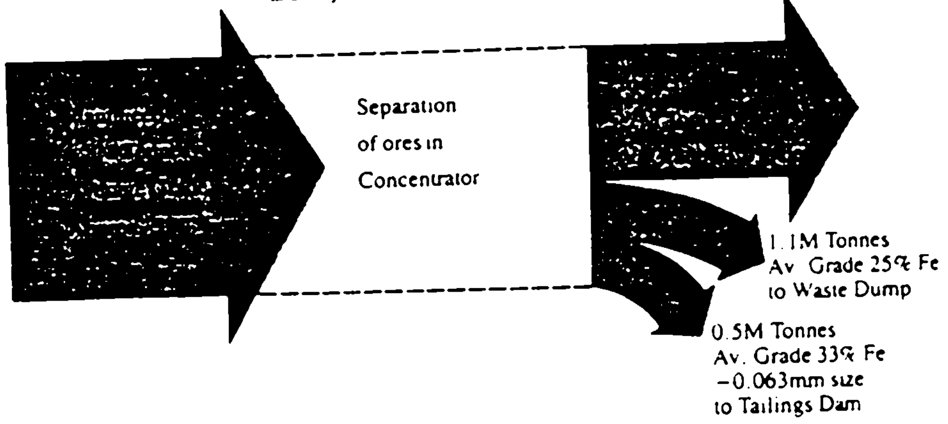
Early in the contact ore-testing programme, it was evident that excellent liberation of the valuable iron ore from waste material was possible over the complete particle size range up to 100mm All ore fractions exhibited minimal near gravity material between the high-density hematite (specific gravity above 4 0) and low-density ferruginous shales (specific gravity below 2.6). Thus it was possible to upgrade the hematite by utilising the difference in specific gravities of the two components through a heavy medium or gravity separation process.
The average grade of beneficiable contact ore fed to the plant contains approximately 55% Fe.

The – 100mm feed to the Concentrator is screened into three fractions for process separation: – 100 + 6mm to the Drum Plant, – 6mm + 1mm to the Cyclone Plant and – 1mm to the Reichert Cones Plant. With the – 100mm + 6mm fraction, Erickson cone studies showed that a static bath WEMCO drum separator would be appropriate. Separation is achieved at a single specific gravity over the entire – 100mm + 6mm particle size range. Some 500 tonnes per hour (average) of 65% Fe is produced in the Drum Plant.

For the – 6 + 1mm fraction, heavy medium separation in a dynamic separatory vessel – the DSM cyclone – is used. Approximately 225 tonnes per hour (average) product of 62% Fe is produced in the Cyclone Plant.

Various processing methods were considered during the test work of the very fine ore fraction (– 1mm) The Reichert Cone, an Australian invention, was selected as the most appropriate means of producing high-grade fines Approximately 150 tonnes per hour (average) of 62% Fe is produced in the Cones Plant.

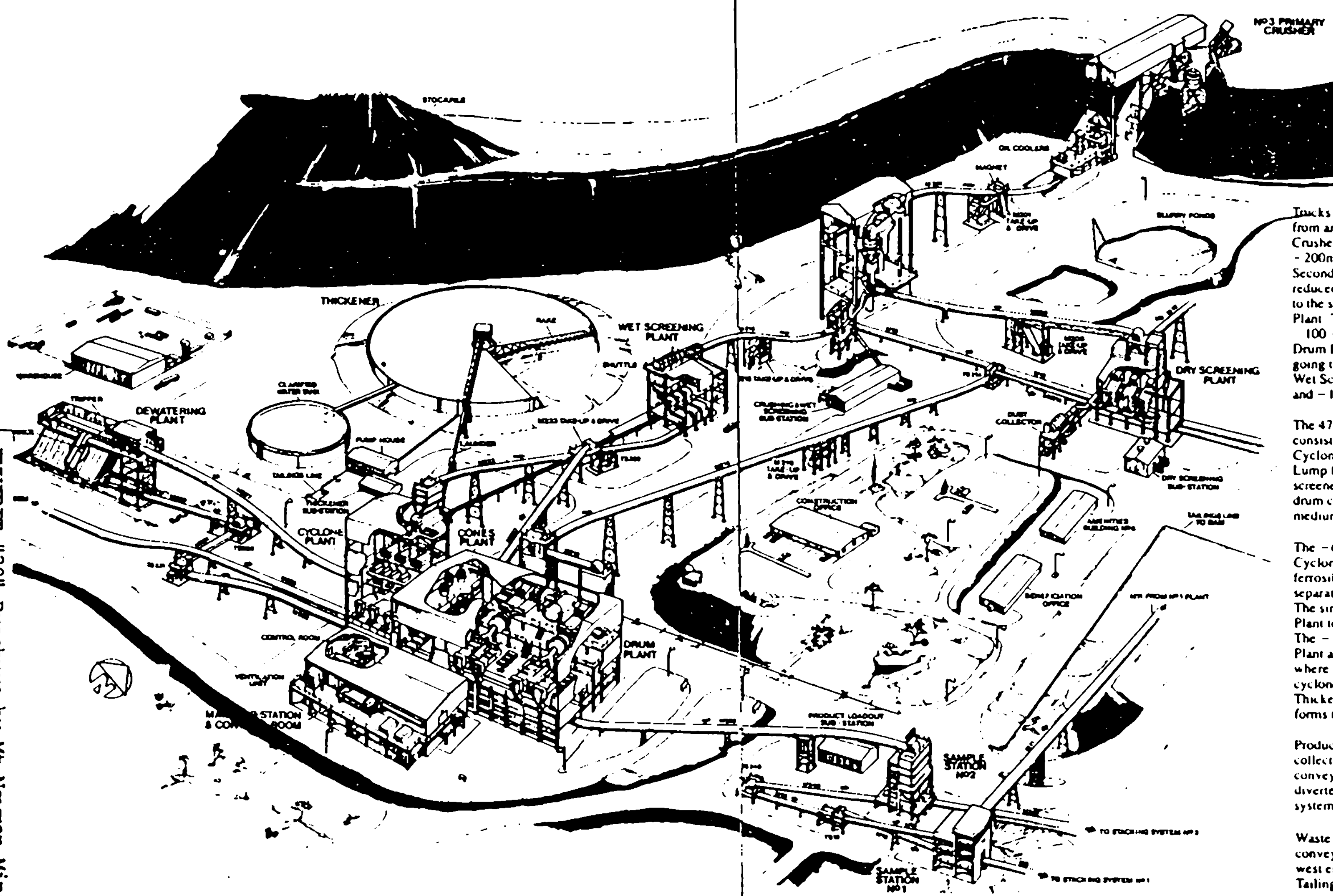
The medium used in the Concentrator consists of spherical ferro-silicon, milled ferro-silicon and magnetite. Approximately 1 800 tonnes per year is used.



The Annual flow of ore through the plant. Based upon the above figures, the overall iron recovery for the plant is 88.3% Fe.

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Plant Layout



Trucks dump ore directly from the pit or from an adjoining stockpile into Primary Crusher No 3, which reduces it to - 200mm The ore is conveyed to Secondary Crusher No. 3, where it is reduced to − 100mm, and then conveyed to the surge bin in the Dry Screening Plant The feed is screened, with the 100 + 6mm lump material going to the Drum Plant and the − 6mm fine material going to the Wet Screening Plant The Wet Screening Plant produces −6 + 1mm and − 1mm products

The 47m high Concentrator building consists of the Drum Plant, Cones Plant, Cyclone Plant, and maintenance area. Lump feed to the Drum Plant is wet screened and separated in a revolving drum containing ferrosilicon/magnetite medium

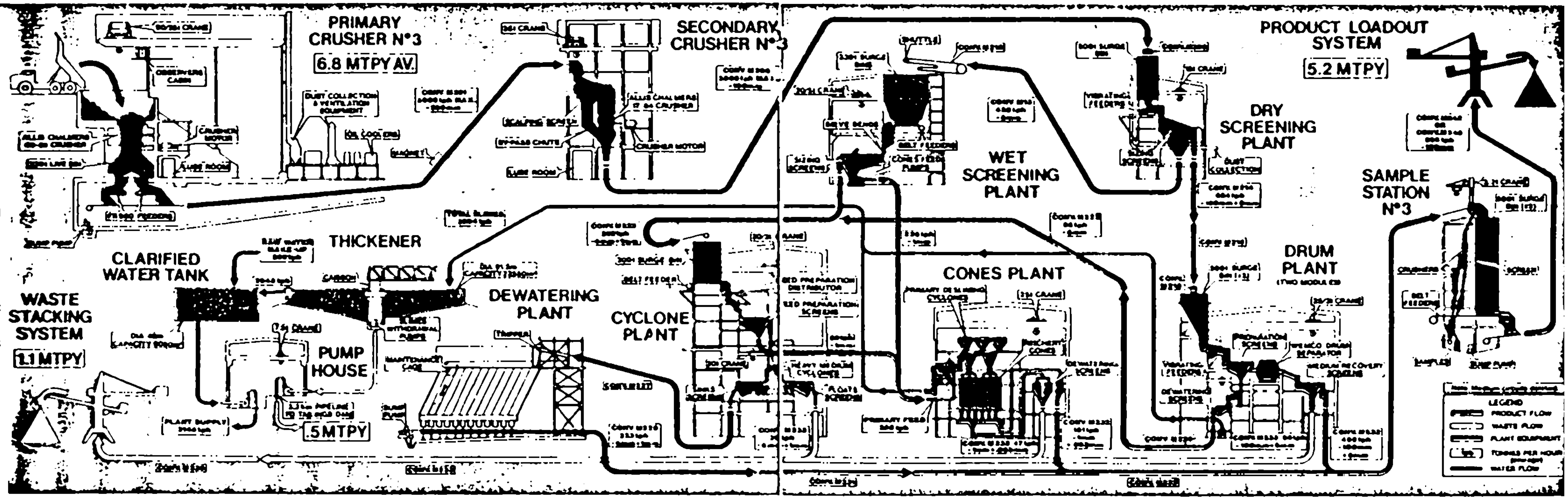
The −6 + 1mm material is fed to the Cyclone Plant, where it is mixed with the ferrosilicon/magnetite medium and separated by dynamic forces in cyclones The sinks product passes to a Dewatering Plant to reduce the free moisture content The − 1mm fines from the Wet Screening Plant are pumped to the Cones Plant, where they are cyclone deslimed The cyclone overflow (slimes) gravitates to a Thickener, whilst the cyclone underflow forms the feed to the Reichert cones

Products from the three plants are collected on a common belt and conveyed to the Sample Station and then diverted to either of the product loadout systems

Waste material from the three plants is conveyed to an automatic stacker at the west end of the mine
Tailings withdrawn from the Thickener are pumped 3 2km to a tailings dam at the east end of the mine
Plant control is fully automatic, with the computer housed in the Main Control Building

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Flow Diagram



The Ore Flow

The flow diagram describes the passage of ore through the total complex and indicates the rate, average grade, and size of the material moving between facilities

Plant production capacity is currently 5 2 million tonnes per year (MPTY) when treating average grade feed, i e 55% Fe Total product output ranges from 3 9 MTPY with low grade feed to 6 2 MTPY with higher-grade feed

Waste Products

Approximately 170 tonnes per hour of water is pumped with the tailings Experiments are being conducted to use the waste water for dust suppression on the mine to save this valuable resource Waste material and tailings are monitored to check on % Fe

The Separating Medium

Medium circuits are not shown on the diagram because of their complexity A mixture of ferro-silicon and magnetite is used as the medium to separate ore and waste In the Drum Plant the separation density (specific gravity - SG) is 3 0 SG and in the Cyclone Plant 2 7 SG Approximately 1 050 tonnes of ferro-silicon and 750 tonnes of magnetite are used throughout both plants each year

Sampling

The product leaving the Concentrator passes through the Sample Station where the separation, Fe content, and particle size of the material is analysed This quality control ensures that the product is acceptable and that the plant is operating efficiently

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Plant Operation

The Beneficiation Plant is manned on a four-shift continuous roster system giving 24-hour coverage 7 days a week

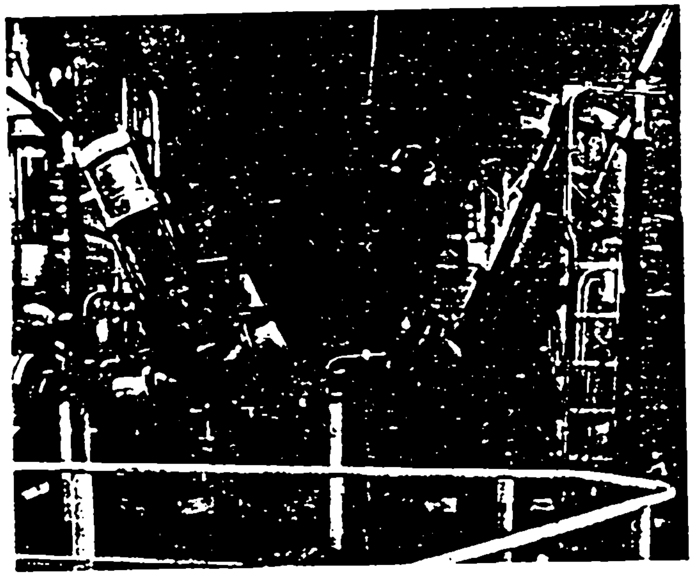
A foreman, leading hand, control room operator and four plant attendants cover the whole plant and are assisted by the automatic control and monitoring system. At the Primary Crusher, an attendant controls the tipping of trucks and monitors the type of ore for acceptance by the plant. Another attendant inspects all equipment between the crushers and the Concentrator building. Within the building, one attendant oversees the operation of both Drum Plants, and another the operation of the Cyclone and Cones plants. The leading hand is mobile, and covers the waste stacking, slimes disposal, and product loadout systems.

Plant Control

In the Control Room, the operator monitors all process control loops and alarms through two video consoles and the push-button sequence start panel. Sixteen closed-circuit television cameras cover important areas where attendants may not be present. The Control Room operator often directs the activities of attendants in the plant. The detailed alarm information he receives allows him to send attendants straight to a problem rather than just the general area, which improves efficiency and reduces time spent in fault finding.

Plant attendants take manual product samples, readings, and make visual observations about their area. This information can indicate changes in the operating conditions of the plant which may not be detected by the control system, but may be interpreted by the Control Room operator A metallurgist recommends changes in set control points of the process which are effected by the Control Room operator All such changes are logged, so that the plant metallurgist and control engineer can refine the process system further.

In general, changes are not made to minor set points unless really necessary, thus maximizing the benefits of the automatic control system.



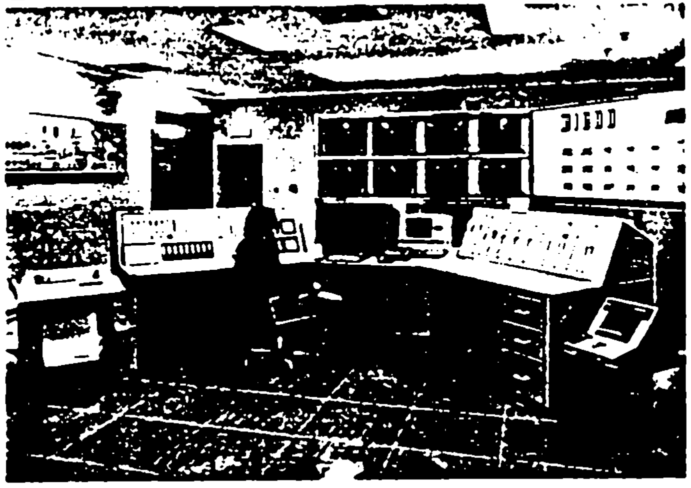
Pneumatically Operated Automatic Valves control medium flow through the cyclone plant.

Plant Maintenance

Wherever possible, minor maintenance of the plant is scheduled into sectional shutdowns of one or two-hour duration, while the remainder of the plant continues to operate. Surge bins throughout the plant facilitate this operation. Regular weekly half-day shutdowns allow those items which cannot be maintained during operation to be covered. These periods are used by Production personnel for recharging the ferro-silicon and magnetite bins, process adjustments, and clean-up in areas which cannot be covered during production time.

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Plant Automation



The Control Room Operator Monitors product flow through the Beneficiation Plant.

The control of the Beneficiation Plant was conceived as a fully automated system, with one central control room in which an operator could direct the operations of all plant areas.

The system achieves a high degree of reliability by eliminating operator errors induced by the complexity of activities required during start-up and shutdown, and minimising operating costs in terms of energy usage, medium loss, and maintenance.

Automatic Control

In the main control building, the control room operator can start and stop each individual plant area, and also monitor and change plant process control variables, such as conveyor tonnage rates and heavy media densities, through a colour television display monitor and keyboard. Access to information on all aspects of plant operations is provided by a computer terminal on the operator's console.

All plant equipment directly associated with the process and providing plant services is monitored by the data-logging computer located in a room adjoining the control area.

To provide for maintenance requirements, local 'Start/Stop' stations are provided on all equipment. These are used only when the plant is shutdown, although 'Stop' push buttons are active at all times.

Sequence Control and Data Logging

Sequence control, which is the consecutive start-up and shutdown of process equipment in the correct order, is performed by a system of eight General Electric programmable logic controllers (P.L.Cs) distributed throughout the plant. These units also provide interlocking between each of the plant areas, together with communication of all equipment alarm and status of information to the central data logging computer – a Honeywell H716. This computer system provides alarm printouts and status display information to the control room operator. Data is obtained via the P.L.C. units and is updated every three seconds. Shift logs, giving plant production tonnages and plant area running times, are automatically generated at the end of every shift. Daily and monthly summary logs are produced similarly. Analytical programmes provide data on plant performance or alter the set points for various process control loops.

Process Control and Instrumentation

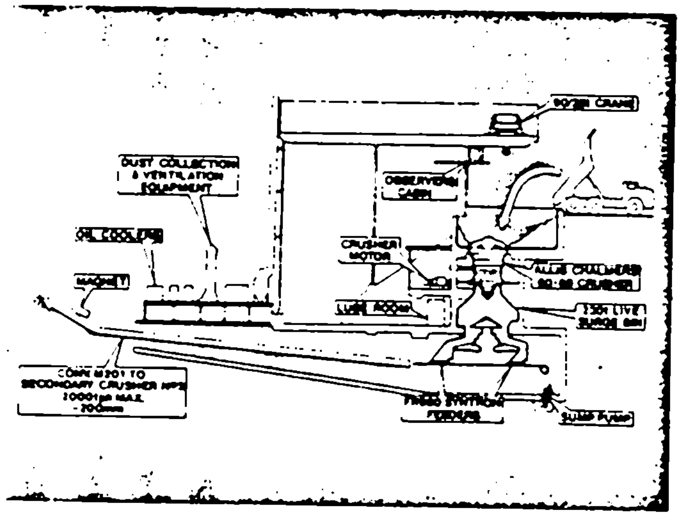
Control of process variables is achieved through a Honeywell TDC2000 analogue processor system located in the data logging equipment room. The system is micro-processor based and is monitored by the operator through a colour television display, with set points altered through a desk mounted keyboard.

Process monitoring instruments installed throughout the plant include belt-weighers, density gauges, and bin and sump level transmitters. All pneumatically-operated valves and chute gates are fitted with limit switches. Flow and pressure switches are utilised to monitor process water and slurry flows throughout.

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Ore Handling Plant

Primary Crusher No. 3



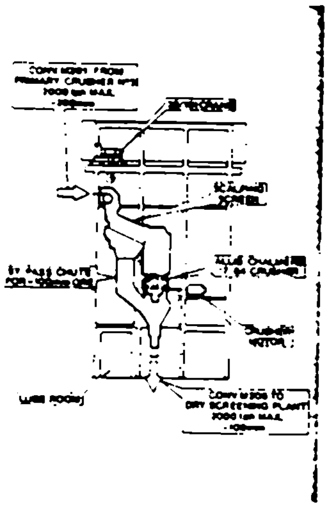
The Allis Chalmers 60-89 gyratory crusher is housed in a reinforced mass concrete structure built into rock. Some 4 240 cubic metres of concrete was used in its construction. The cantilevered crane access allows room for 200 tonne trucks to tip into the hopper, which has tractor access for cleaning.

A fully hydraulic maintenance platform for hydroset removal gains access to the surge bin at ground level. Large cut-off gates above the two Syntron FR980 vibrating feeders retain the ore flow during maintenance periods.

Ventilation, dust collection, and oil cooling equipment is mounted on a services platform over the tunnel for easy maintenance access. The oil cooler also serves the Secondary Crusher No. 3. The motor and switch rooms are pressurized and the observer's cabin is fully air-conditioned.

Water from the sump and slurry discharge is pumped into slurry ponds.

Secondary Crusher No. 3

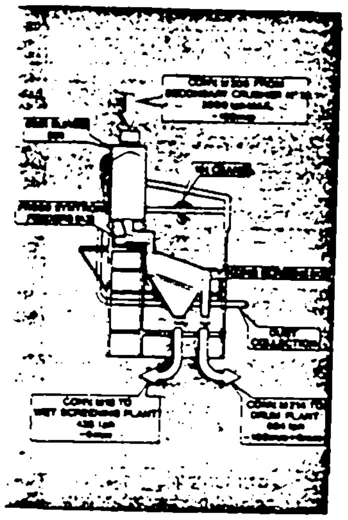


The 200mm feed to the Secondary Crusher passes through a single deck − 100mm bypass screen before entering the Allis Chalmers 17-84 hydrocone crusher.

The building has been designed for the installation of a second crushing system at a later stage. Use will be made of the existing overhead crane, lubrication room and dust collection system.

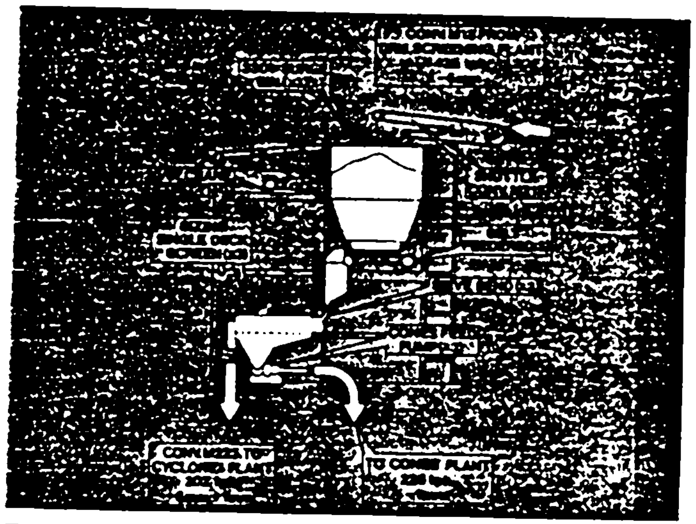
EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Dry Screening Plant



This plant was part of a fines screening system before being incorporated into the Beneficiation Plant process. The −100mm ore is stored in the 500-tonne capacity surge bin, and is distributed to the Allis Chalmers double-deck screens by the Syntron FR980 vibratory feeders. The two products, −6mm and −100mm +6mm, are fed to the Wet Screening Plant and Drum Plant respectively. Neucleonic detectors control surge bin levels, and both products are weighed as they leave the plant.

Wet Screening Plant



The −6mm ore passes along an automatic shuttle conveyor before being evenly distributed over the three 330-tonne capacity surge bins. Belt feeders move the ore through a mixing chute and sieve bend where some of the −1mm material is separated. The Allis Chalmers single-deck screen carries out further sizing. The −1mm material is pumped to the Cones Plant, while the −6mm +1mm product is conveyed to the Cyclone Plant. Ultrasonic level detectors control fine levels.

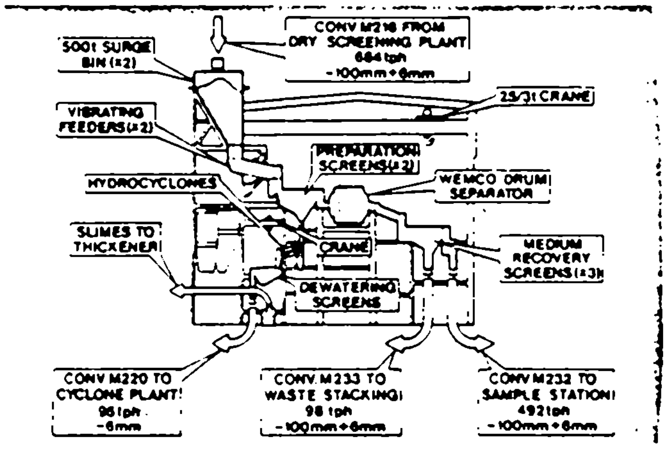
SUPREME COURT WESTERN AUSTRALIA

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Concentrator

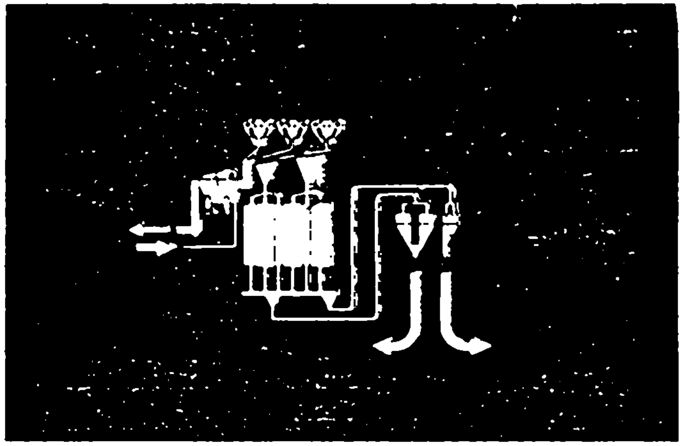
Drum Plant

Two Modules – 'A' and 'B' Plants.
The – 100mm +6mm feed is stored in two surge bins each of 500 tonnes capacity. After screening, which removes the degraded fine material, the ore is mixed with medium in a revolving drum. The product and waste material pass onto screens for medium recovery then fed onto the product and waste conveyors.



Cones Plant

The – 1mm feed from the Wet Screening Plant is pumped into the primary feed sump and desliming cyclones. The ore gravitates through the Reichert Cones and the product and waste material is again deslimed before being dewatered on screens and fed onto the conveyors.



Cyclone Plant

From the Wet Screening Plant, the –6mm + 1mm material is fed into a 300-tonne capacity surge bin. The ore is belt fed to a distributor and feed preparation screen before gravitating to the DSM heavy medium cyclones. The product and waste material pass onto screens for medium recovery before being fed onto conveyors.

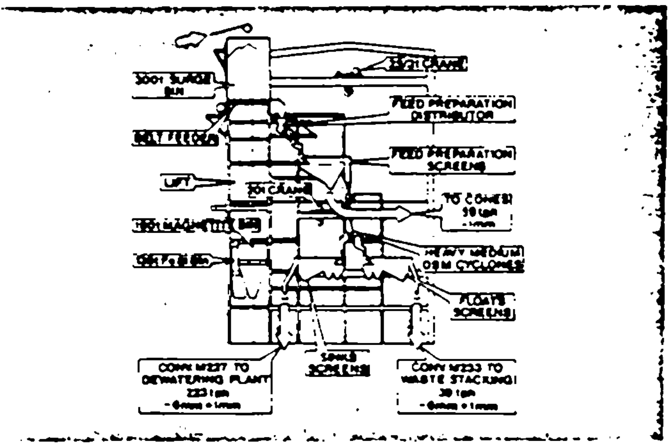
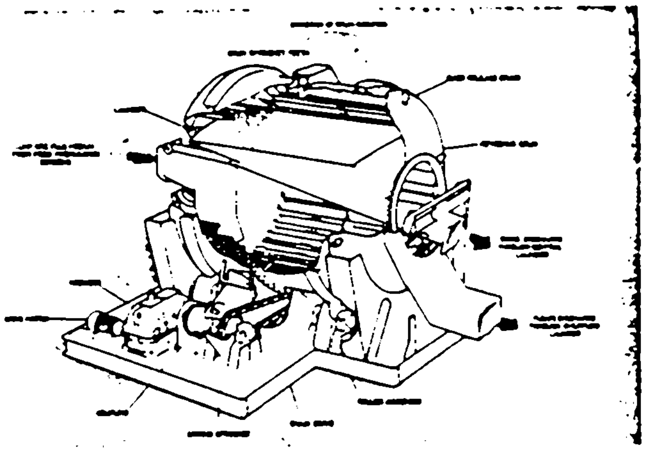


EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Principle of Operation

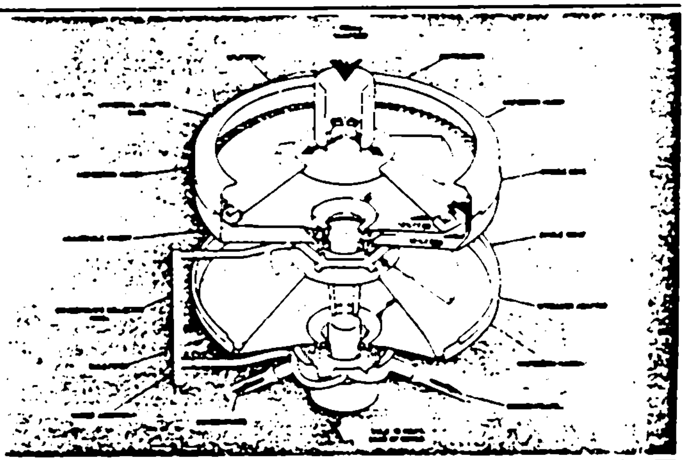
Drum Plant

The ore is fed into the slowly rotating drum which contains a static bath of high-density ferro-silicon/magnetite medium. The light shaly waste floats out from the drum discharge port, while the heavy iron ore particles sink and are carried up in the lifters on the side of the drum and dropped into a launder, which is flushed out using medium.



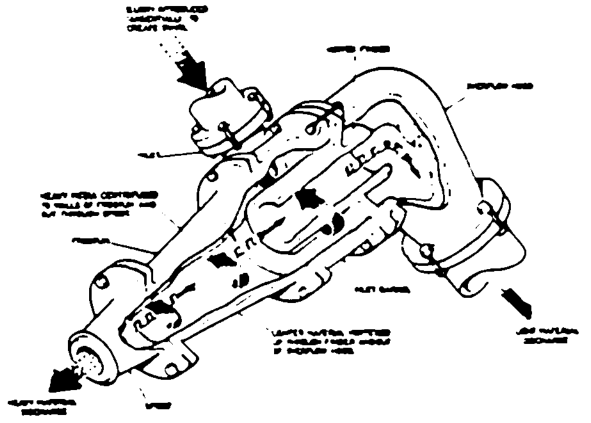
Cones Plant

The ultra-fine feed is fed into the top of the distributor and spreads out over the conical surface. As the laminar flow gravitates down the cone, the heavy particles fall to the bottom of the flow. Small slots at the edges of the conical section allow the heavy particles of ore to fall through, while the light waste material passes over.

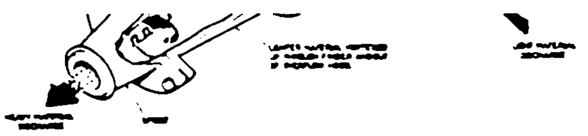


Cyclone Plant

The mixture of ore and high-density ferrosilicon/magnetite medium is fed tangentially under pressure into the cyclone. Forces induced in the cyclone gravitate the heavy iron ore particles to the outside of the stream, where they move downward and out of the product spigot. Light shaly particles remain in the centre portion of the stream and are forced upward through the cyclone and out of the waste overflow

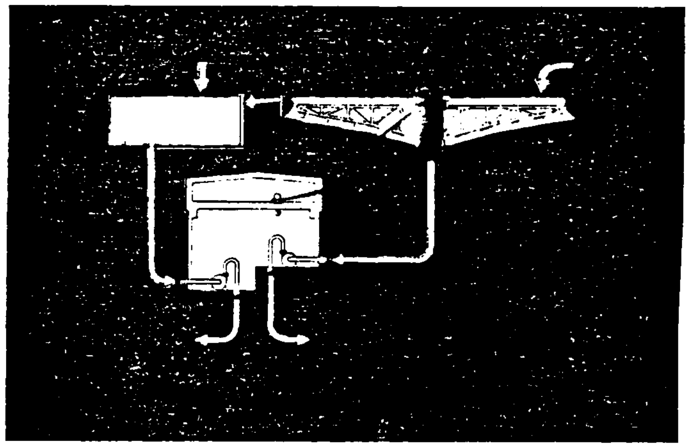


centre portion of the stream and are forced upward through the cyclone and out of the waste overflow



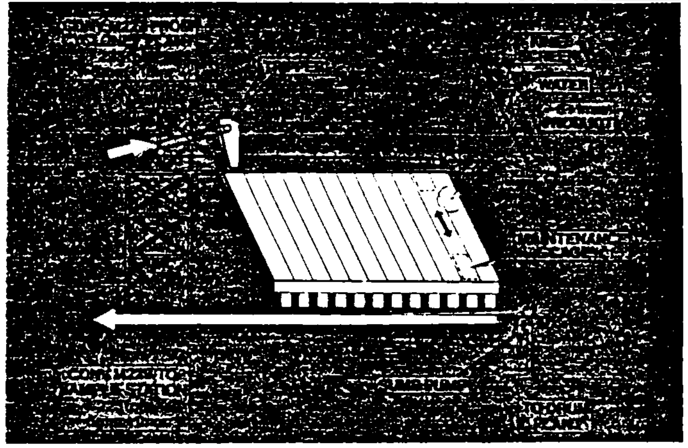
Other Facilities.

Thickener



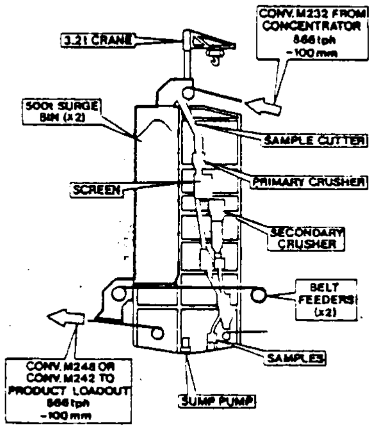
Waste water containing slimes from the process gravitates from the Concentrator to the Thickener. Solids sink to the bottom and are raked towards the centre, from where they are pumped to a tailings dam. The clear water overflows to the clarified water tank for reuse. Approximately 3 000 kl circulate every hour.

Dewatering Plant



The material is uniformly distributed over the bunkers by a tripper. Product from the Cyclone Plant contains approximately 12% moisture and is stored in a dewatering plant for eight hours to reduce the water content to 6%. The water is recycled into the Drum Plant.

Sample Station



As the product from the Concentrator enters the two 500 tonne capacity surge bins, it is sampled by a cutter. The sample is crushed, dried, and screened before being taken to the Assay Laboratory for metallurgical analysis.

EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

Plant Construction

Administration

The Beneficiation Plant was designed by Mt. Newman engineers in conjunction with Mitchell Cotts Consortium and other consultants. Bechtel Pacific Corporation Limited administered the purchasing and construction of the Project and Mt. Newman personnel provided overall control and fully commissioned the plant in association with equipment suppliers and consultants.

Industrial

Of the 1,237,913 direct manhours worked to the end of March, 1979, only 5240 were lost due to industrial action.

Safety

The Project enjoyed a remarkable safety record, with an average All Injury Frequency Rate of 38.1. Commendations were received from the Industrial Foundation for Accident Prevention with two awards for periods in excess of 100 000 hours without a lost time accident.

Construction Schedule

Construction started in November, 1977, and the Beneficiation Plant was ready for use by the end of March, 1979.
Commissioning started in the Dry Ore Handling area in November, 1978, and ore was introduced into the Primary Crusher on February 20, 1979. The 16 month construction period meant that the project had been completed three months ahead of schedule.

Statistics

Total man hours to April 30th, 1979, were 1,365,000. Peak manpower on site (November, 1978) was 631 including 472 direct labour

- Total steel (excluding machinery) – 7800 tonnes
- Total earthworks – 590,094 cubic metres
- Concrete – 11,170 cubic metres
- Cable Ladder – 18,494 metres
- Conduit – 40,875 metres
- Piping – 23,374 metres
- Cable – 232,846 metres

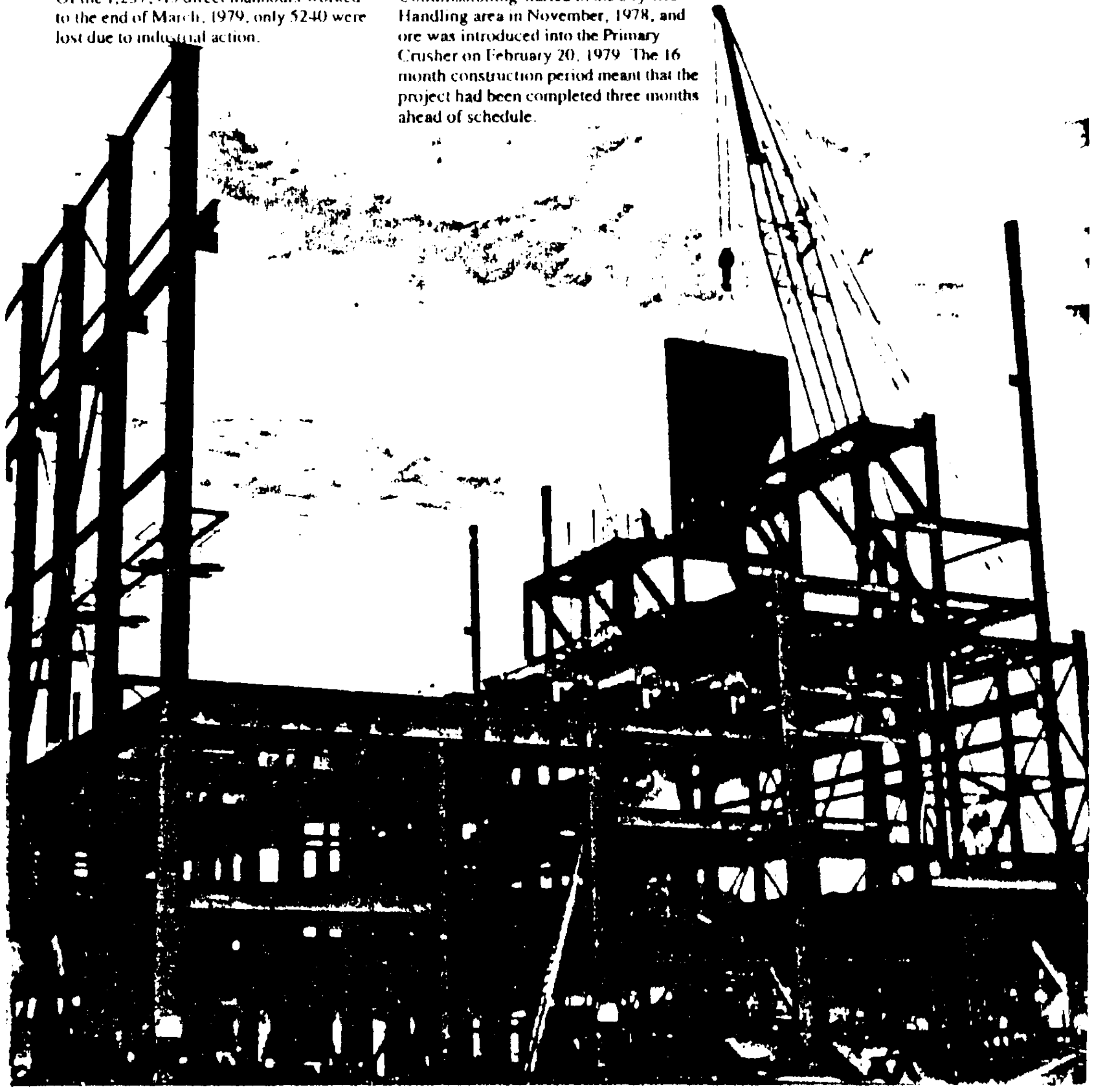
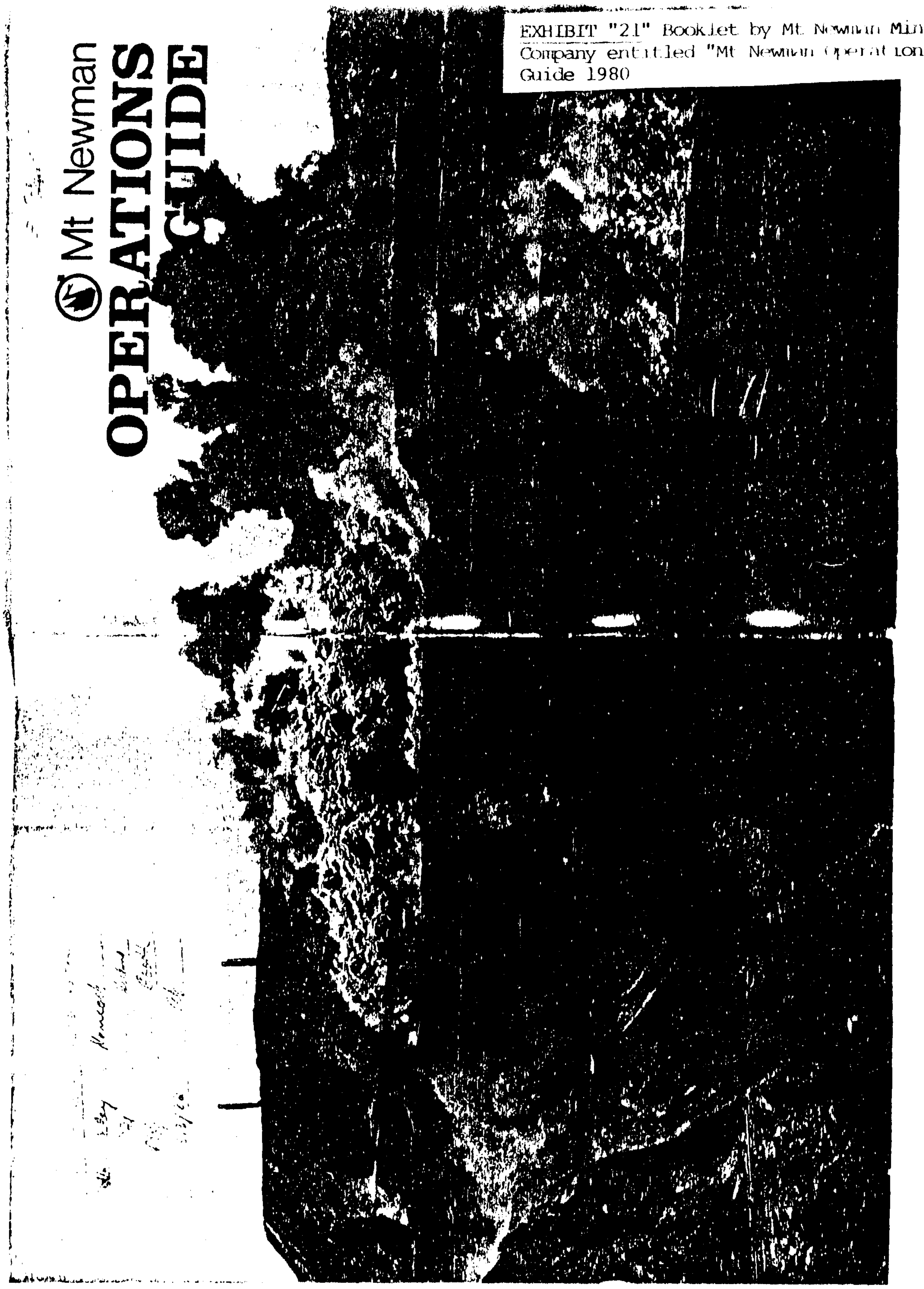


EXHIBIT "20" Brochure by Mt Newman Mining Company entitled "Beneficiation Plant" 1979

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide 1980



Mt Newman
OPERATIONS GUIDE

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

THIS booklet is published as your guide to the Mt Newman Joint Venture's iron ore, mining, beneficiation, railing, processing and shiploading operations. Information contained was correct at June 1st. 1980.

COVER: Blasting new bench on the East Pit of Mt Whaleback.

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

Mt Newman Joint Venture

1

Mt Newman Mining Co. Pty. Limited manages the Mt Newman Iron Ore Project on behalf of the Members of the Mt Newman Joint Venture, an enterprise in which Australian interests have a 60 percent holding. The company is a wholly-owned subsidiary of The Broken Hill Proprietary Co. Limited.

Mt Newman, which holds contracts for the supply of high grade iron ore to major steel mills in Australia and overseas, started mining operations in January, 1969. Its Mt Whaleback mine at Newman, in the Pilbara Region of Western Australia, is the largest single, open-pit iron ore mine in the world.

Ore from Mt Whaleback and another orebody within Mt Newman's Mineral Lease Area is hauled to Port Hedland, on the North West seaboard, over a 426 km privately-operated railroad. At Port Hedland, it is processed, stockpiled and reclaimed for shipping.

At June 1, 1980, Mt Newman had shipped a total of 269 million tonnes of iron ore to Australia's BHP steelworks and Japanese, Asian and European steel mills. Although the project was planned in 1967 to handle annual shipments for five million tonnes, production has expanded over the years*—

First year	6.6 million tonnes
Second year	13.2 million tonnes
Third year	19.6 million tonnes
Fourth year	23.6 million tonnes
Fifth year	28.4 million tonnes
Sixth year	31.3 million tonnes
Seventh year	28.0 million tonnes
Eighth year	29.3 million tonnes
Ninth year	29.1 million tonnes
Tenth year	32.3 million tonnes
Eleventh year	28.13 million tonnes

*Mt Newman's operating year is to March 31.

HISTORY

The first white men known to have visited the area were explorer Ernest Giles and his second-in-command Alex Ross who named the surrounding Ophthalmia Range during an expedition in 1876. Giles was suffering from an eye infection known as Sandy Blight, or Ophthalmia, when the range was first sighted!

The area takes its name from Mt Newman, a peak 1053 m above sea level which dominates the eastern end of the range. The landmark was named in 1896 by a mapping expedition party whose 30 year-old leader, Aubrey Woodward Newman, had died of typhoid fever a few months earlier.

A cattle station was established in the district by John Bates in 1901 but it was not until 1957 that the potential of a nameless, humpbacked hill 21 km south of Mt Newman was discovered. The honour went to a Western Australian prospector, A.S. "Stan" Hilditch, who was searching for manganese when he noted outcropping iron ore on the western end of this hill, now named Mt Whaleback

Samples, which he sent to his Sydney partner, engineer C.H. Warman, assayed at 68.8 per cent iron. In 1960, when the Commonwealth Government removed its 30-year-old embargo on the export of iron ore, Hilditch and Warman immediately staked claims to Mt Whaleback and surrounding areas in the eastern Pilbara and were granted temporary reserves in 1961-2.

During a world quest for new mineral prospects in 1963, a team of executives from AMAX Inc., of the United States, heard of Mt Whaleback's potential from Warman. After a preliminary examination, AMAX formed Mt Newman Iron Ore Company Limited to develop the Mt Whaleback deposit. After incorporation on July 10, 1963, the new company signed an option agreement with Warman and Hilditch. In the following year, AMAX invited CSR Limited to participate in future testing and ultimate development of the reserves. On September 14, 1964, CSR acquired 45 per cent of the shareholding in Mt Newman Iron Ore Company Limited and, on June 10, 1965, increased its interest to 50 per cent. The company was reconstructed in April, 1967, when all the present participants became equal shareholders.

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

In August, 1964, Mt Newman Iron Ore negotiated an agreement with the Western Australian Government on the development of the reserves. Early mapping and drilling showed Mt Whaleback contained at least 220 million tonnes of high grade hematite (64 per cent iron content). In November, the Commonwealth Government approved the export of 213 million tonnes of Mt Newman iron ore.

In January, 1965, Japanese steel mills signed a letter of intent to purchase ore. AMAX and its U.S. consultants estimated the construction cost of a five million tonnes per year project at US $160 million and long-term contracts were signed with eight Japanese steel companies for the supply of over 100 million tonnes. In November, 1965, a new estimate of construction costs indicated an increase of US $40 million on the original estimate which would have made the project uneconomic on scheduled shipment rates.

During September, 1966, AMAX, CSR and The Broken Hill Proprietary Co. Limited agreed in principle on conditions under which a Joint Venture could be undertaken. BHP agreed to become a major purchaser of Mt Newman ore and it was agreed that annual shipments to Japan should be increased. In January, 1967, Mt Newman Mining Co. Pty. Limited was formed by BHP as a wholly-owned subsidiary to manage the project on behalf of the Joint Venturers.

Five per cent of the project was sold to Seltrust Iron Ore Limited, a subsidiary of the London mining and investment house Selection Trust Limited. Later, two major Japanese trading companies, Mitsui and Co. Limited and C. Itoh and Co. Limited, took a 10 per cent interest in the project through Mitsui-C.Itoh Iron Pty. Limited in which Mitsui has a 70 per cent interest and C. Itoh 30 per cent. This formed a Joint Venture comprising:

AMAX Iron Ore Corporation, a subsidiary of AMAX Inc., which holds a 25 per cent interest.
Pilbara Iron Limited, a subsidiary of CSR Limited, 30 per cent.
Dampier Mining Co. Limited, a subsidiary of The Broken Hill Proprietary Co. Limited, 30 per cent.
Seltrust Iron Ore Limited, a subsidiary of Selection Trust Limited, 5 per cent.
Mitsui-C.Itoh Iron Pty. Limited, 10 per cent.

The Joint Venture Agreement came into force in April, 1967, and Bechtel Pacific Corporation was appointed construction administrator. In one of the most intensive engineering and construction feats in Australian history, the participants established an open-pit mine on Mt Whaleback, ore-crushing, train loading and industrial support facilities and a new town, Newman. The two-year drive also produced one of the world's longest privately-operated railroads on the 426 kilometre route between the mine and Port Hedland on the Indian Ocean. At Port Hedland, the same herculean effort created a 140-hectare train unloading, tertiary crushing, stockpiling, reclaiming and shiploading complex at Nelson Point with industrial support facilities and a new oceanside suburb at Cooke Point.

NEW PLANT

On September 23, 1976, a second ore-handling plant was commissioned at Port Hedland, lifting annual production and shipping capacity to more than 40 million tonnes and total investment in the project to $735 million. Incorporating advanced ore-handling techniques, the plant provides a basis for expansion beyond 40 MtPY.

Early in 1978, work started on the construction of an iron ore beneficiation plant at the mine and this project was completed early in 1979. The plant, its auxiliaries and associated infrastructure cost about $85 million, lifting total investments in the project to almost $850 million. Designed to process approximately seven million tonnes of contact or low grade ore annually to produce approximately five million tonnes of high grade product, it increases Mt Newman's recoverable high grade ore reserves by about 140 million tonnes and extends the life of the deposits by several years.

When the Western Australian Government approved the Mt Newman Iron Ore Project in 1964, the participants agreed to undertake secondary processing of iron ore from the mineral lease at the rate of 0.5 million tonnes per year by 31 March, 1981, increasing to 2.0 MtPY by 31 March, 1985. The beneficiation plant, a secondary processing installation with vastly greater capacity, was commissioned two years ahead of the date set by this agreement.

Work will begin this year on up-grading the No. 1 Screening and Crushing Building at Port Hedland. Most of this work will involve cutting down the congestion in the building, while making clean-up and dust-control improvements. The No. 2 Ore Handling Plant will be fitted with two extra screens during this time, to compensate for some of the lost production facility resulting from the work on the No. 1 plant. Stackers 3 and 4 systems at the Port will also be up-graded during this period, to enable each to handle 5 100 tonnes an hour as against their existing capabilities of 4 000 tonnes an hour.

Mt Newman is looking to the future with confidence. It has a potential for expansion beyond 40 million tonnes per year based on a solid foundation of substantial high grade iron ore reseves, capable and experienced people and an infrastructure supporting the largest single open-pit iron ore mine in the world.

SUPREME COURT WESTERN AUSTRALIA

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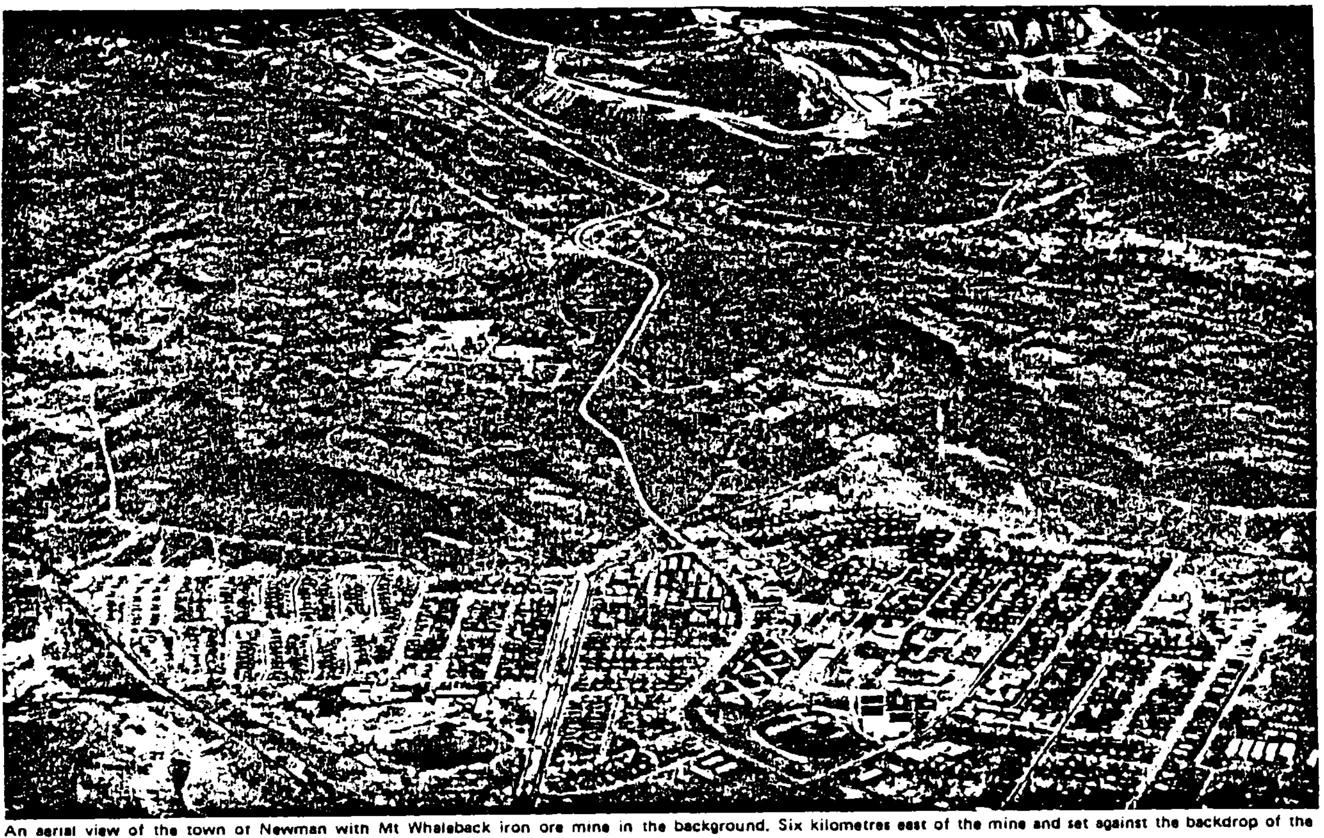

□ An aerial view of the town of Newman with Mt Whaleback iron ore mine in the background. Six kilometres east of the mine and set against the backdrop of the Ophthalmia Range, Newman is a modern town of 5,500 people.

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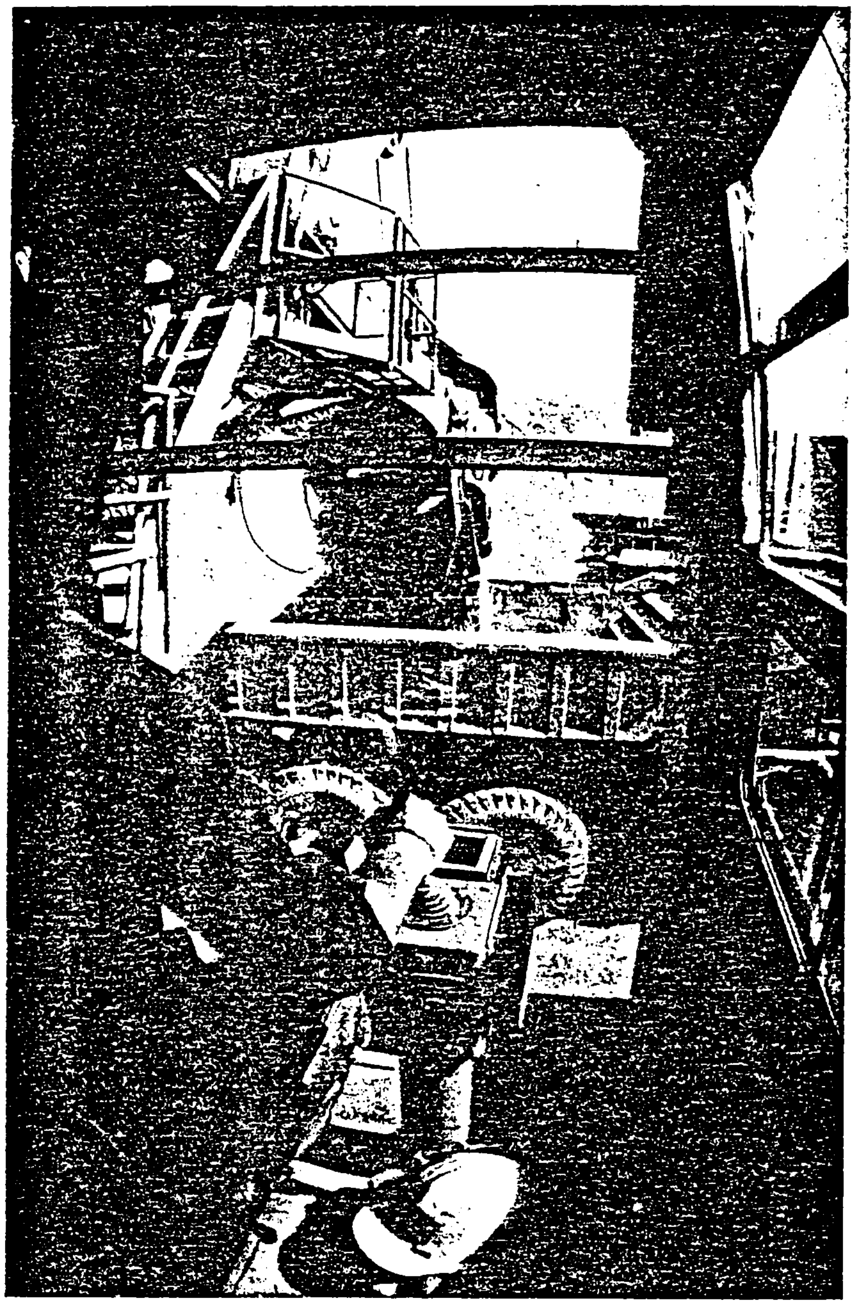

Shovel driver Eddie Mackie operating one of the giant P & H Shovels on Mt Whaleback, loading waste into a 200 - tonne haulpack.

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Mining operations

2

Mt Newman's iron ore mining operations are centred on Mt Whaleback, a 5.5 km-long hill rising 185 metres above spinifex-covered plains south of the Ophthalmia Range. Development of the mine started at the eastern end of Mt Whaleback in January, 1967, and more than 2.5 million tonnes of overburden and low-grade material were removed before production mining began. Much of this material was used to develop a wide ore-haulage road down the southern flank of the hill to a two-stage crusher system.

When production mining started in January 1969, three benches had been developed - one at 731 metres above sea level, one at 747 metres and the third at 762 metres. At June 1, 1980, work was in progress on 14 benches between 565 and 780 metres above sea level.

The mine has a production capacity of more than 40 million tonnes of iron ore and about 60 million tonnes of waste material a year. Daily material movement is between 240000 and 220000 tonnes from which between 90000 and 140000 tonnes of crushed ore is produced for railing to Port Hedland.

Ore grade drilling and sampling on the 15 m high benches establish the production areas before primary drilling crews move in to drill rows of blastholes up to 38 cm in diameter with Bucyrus-Erie 60R drills. Powder crews charge the drillholes from ANFO supply trucks with a mixture of ammonium nitrate and gas oil (distillate) and ANZOMEX boosters. The charges are initiated with detonating fuse.

Blast shattered ore is scooped by eight crawler-mounted electric-powered shovels of 7.6 m^3 capacity, eight 9.2 m^3electric shovels, two 17 m^3 electric shovels and two 18.5 m^3 electric shovels able to scoop more than 50 tonnes of material at a single bite. The shovels feed the ore into a fleet of diesel-electric WABCO Haulpak rear dump trucks which haul it to the crushing plant. The fleet comprises fifty-three 109 tonne trucks and twenty-two 189 tonne trucks.

Auxiliary mine equipment includes five Caterpillar 992C, one 992B, one 988B and two Dart D600 front-end loaders. Five Caterpillar D9H and fourteen D9G tracked bull-dozers and eight Caterpillar 824B and two 824C tyred bulldozers clean up the benches around the working shovels and maintain dumping areas.

Thirteen 68-tonne Haulpak trucks have been adapted for use as water-sprinkler units. These trucks, each of 45000 litres capacity, spray water over the benches and along the haulroads to minimise dust. A haulroad reticulation system is being developed to improve dust suppression.

Overburden and low-grade ore is dumped on stockpiles on the perimeters of the mine.

IRON ORE CRUSHING

The original two-stage (primary and secondary) iron ore crushing plant at Newman has been in operation since January, 1969. A second two-stage, plant, incorporating improved design features resulting from experience gained operating the first one, was commissioned on October 1, 1971. The two crushing systems are capable of handling up to 160000 tonnes of iron ore daily.

Production staff, in a tower control room situated between the two primary crushers at the foot of Mt Whaleback, supervise the Haulpak trucks as they approach the crushers, dump the ore, and return up the haul road to the mining benches. Any malfunction in the crushing, screening and ore conveyor systems is pinpointed on a monitoring panel and each section of the complex halts automatically in the event of a breakdown. A lamp on the panel identifies the trouble spot and enables control room staff to direct maintenance crews to the scene with the least possible delay.

Two radio channels link the office with shovel operators and Haulpak drivers, allowing production staff to control the flow of ore from the benches, through the crushing and screening processes to surge piles over rail loadout tunnels.

The Haulpak drivers rear-dump their loads on two sides of each primary crusher. The two primary crushers reduce material of up to 1.5 m in diameter to lumps only 200 mm in diameter and the two secondary crushing installations further reduce the ore to lumps less than 100 mm in diameter.

Primary crushing is by Allis Chalmers 60-89 gyratory crushers housed underground in reinforced concrete chambers. Powered by a 522 kw electric motor, the 6 m crushing head of each primary unit rotates as the trucks empty their loads and the ore is broken between the crushing head and crusher sides. Operations are supervised from overhead control cabs.

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Ore from the primary crushers passes through surge bins into Syntron vibrating feeders and on to conveyor belts which carry it, at a rate of 4000 tonnes an hour, to distribution bins above the two secondary crushing installations.

At this point, the ore passes through feeders and screens into Allis Chalmers gyratory crushers, each powered by a 300 kw electric motor. Reduced to a nominal diameter of less than 100 mm, it then falls on to conveyor belts running to transfer and sampling stations. Samples of up to 200 kg are removed automatically at a pre-set rate for chemical analysis before the ore is transferred to conveyors serving two rail-mounted boom stackers.

TRAIN LOADING

The boom stackers feed surge piles above two concrete tunnels, one 210 m and the other 220 m long, in which ore trains are loaded. One stacker feeds high and low grade ore to piles above the first tunnel at an average rate of 4000 tonnes an hour. The second can be slewed to feed ore to piles above either loadout tunnel

Each reinforced concrete tunnel is served by a rail loop and a complete train can be loaded with 13 700 tonnes of ore in only one hour in either tunnel. A train is reversed into a tunnel until the locomotive driver is instructed to halt by an operator supervising loading operations on a separate two-way radio channel from a control cab high on the side of the tunnel.

In each tunnel, 13 chutes are lowered to gravity-feed ore into the waiting cars from the surge piles above the tunnel roof. As the ore mounts in the cars, the chutes choke automatically and are raised by pneumatic cylinders to the tunnel roof leaving approximately 95 tonnes of ore in each car. When one set of cars has been loaded, the train is moved on and the operation repeated until the entire train has been loaded.

INDUSTRIAL SUPPORT

A 65-hectare site, adjoining the loadout system, carries an industrial support complex including administration offices, general workshop, vehicle workshop, tyre workshop, warehouses, two power stations with a total output of 52 megawatts, fuel and tyre depots, ammonium nitrate stores, railtrack vehicle repair and maintenance centres, sample preparation building and assay laboratory equipped with X-ray fluorescent spectrometers, change-rooms and lunchroom facilities.

An apprentice training centre, catering for up to 100 apprentices, adjoins the site.

BENEFICIATION PLANT

Mt Newman's new Beneficiation Plant, adjacent to the No 1 Crushing System at Mt Whaleback mine, will increase the Joint Venture's reserves of recoverable high grade ore by about 140 million tonnes and extended the life of the deposits considerably. Commissioning of the plant in 1979 discharged the fisst of Mt Newman's secondary processing obligations under its agreement with the Western Australian Govenment.

The Mt Whaleback orebody consists of thick high grade hematite bands and thinner interbedded shale bands. The main ore horizon (Dales Gorge Member) is overlain and underlain by thick shale bands while the upper ore horizon (Joffre Member) is underlain by shale and contains shaly zones within it.

To maintain grade targets for shipped ore, there is a need to process large tonnages of medium and low grade ore — a mixture of high grade hematite and shale which is produced in the general course of mining. Previously, these were not blended with high grade ore but stockpiled on low grade stockpiles, or taken to waste dumps if the grade was less than 54 per cent Fe.

The mixture of high grade hematite and shale which occurs due to mining of the contact zone between high grade ore and adjacent shale is referred to as contact ore. This material, providing feed for the Beneficiation Plant, exhibits good liberation of iron values throughout the size range treated. The new plant permits coarse and medium fractions in the feed to be beneficiated by heavy medium separation and fine ore to be treated by gravity separation (water medium).

Low grade ore from the mine or low grade stockpiles is trucked to a 60/89 primary gyratory crusher which reduces the ore to minus 200 mm. From the primary crusher, the ore is conveyed to a scalping screen ahead of a 17/84 secondary hydrocone crusher. Minus 200 + 100 mm screen oversize is crushed to minus 100 mm; the total minus 100 mm ore is conveyed to a previously existing dry screening plant.

Dry screening produces - 100 + 6 mm lump ore and - 6 + 0 mm fines. The lump ore is conveyed to two 500-tonne surge bins ahead of the two drum plant modules. Ore drawn from the surge bins is wet screened to remove any remaining - 6 mm ore. The "clean" - 100 + 6 mm ore passes into two rotating WEMCO drums (4.27 m diameter x 3.66 m length) where a medium comprising ferrosilicon/magnetite/water separates the ore into high grade sinks (hematite) and low grade floats

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(shale) at a specific gravity of 3.0. The sinks pass over medium recovery/washing screens and then to a common products conveyor. The floats pass over medium recovery/washing screens and then to a common waste conveyor.

The -6+0 mm fines from the dry screening plant are conveyed to three 333 tonne capacity surge bins ahead of a wet screening plant. Ore from the surge bins passes over three sieve bend/sizing screens to produce -6+1 mm oversize and -1+0 mm undersize.

The -6+1 mm ore is conveyed to a 200 tonne surge bin ahead of the cyclone circuit. Ore is fed from the bin to feed preparation screens where any remaining -1 mm material is removed. The "clean" -6+1 mm ore passes into nine DSM cyclones (0.35 m diameter) where a medium comprising ferrosilicon/magnetite/water separates the ore into high grade sinks (hematite) and low grade floats (shale) at a specific gravity of 2.7. The sinks pass over medium recovery/washing screens and then to the cyclone product conveyor. The floats pass over medium recovery/washing screens and then to a common waste conveyor.

The cyclone product passes into a static dewatering bunker where the ore is retained for up to 10 hours to decrease the moisture content from 13 per cent to around 6 per cent. The ore is withdrawn from the bottom of the bunker and passes to the common products conveyor.

The -1+0 mm ore from the wet screening plant is pumped to a Reichert cones plant. This material, together with the -1+0 mm undersize from the feed preparation screens in the cyclone plant, passes to a bank of desliming cyclones ahead of the Reichert cones. Desliming at 0.063 mm is performed with the -0.063 mm slimes gravitating to a thickener. The -1+0.063 mm ore is pumped as feed to the Reichert cones. The eight-cone configuration produces high grade concentrate (hematite) and low grade tailings (shale). The concentrate passes through a dewatering cyclone, over a dewatering screen and then to the common products conveyor. The tailings pass through a dewatering cyclone, over a dewatering screen and then to the common waste conveyor.

Slimes entering the thickener at about 4 per cent solids density are thickened to 35 per cent solids density. The underflow from the thickener is pumped to a slimes dam in the eastern section of Mt Whaleback.

The total -100+0.063 mm reject from the drum, cyclone and Reichert cone circuits is conveyed to a waste stacker and reject stockpile in an area south-west of the Whaleback deposit.

The total -100+0.063 mm product from the drum, cyclone and Reichert cone circuits is conveyed by the common product conveyor via a sampling plant, where a cut of the ore stream is taken, to two 500 tonne product surge bins. Ore from the surge bins passes to the two stackers which stack ore on to the train loadout stockpiles together with normal high grade ore production through the No. 1 and No.2 mine crushing plants. Ore is withdrawn from the train loadout stockpile and railed to Port Hedland for tertiary crushing/screening and stockpiling.

PRODUCTION CAPACITY

The Plant has a nominal capacity of 6.8 MtPY of feed. For an average feed grade of 55.1 per cent Fe, the following products are produced:

PRODUCT	Size (mm)	MtPY	% Fe
Drum Sink	-100+6	2.95	65.0
Cyclone Sink	-6+1	1.34	61.7
Cone Concentrate	-1+0.063	0.91	61.7
Coarse Reject	-100+0.063	1.10	25.0
Slimes	-0.063	0.50	33.0

Plant recoveries are as follows: Mass yield, 77 per cent; Fe unit recovery, 88 per cent.

Tertiary crushing and screening processes at Port Hedland can yield 2.69 MtPY of -30+6 mm lump ore and 2.51 MtPY of -6 mm fines. This corresponds to a lump yield of 52 per cent.

MARRA MAMBA ORE DEVELOPMENT

Development of Marra Mamba Formation iron ore deposits within the lease area is expected to contribute significantly to the Venture's operations.

The Venture has drilled reserves of about 500 million tonnes of Marra Mamba iron ore including 460 million tonnes adjacent to the Mt Whaleback mine — which is Brockman Formation ore. There are additional extensive deposits, not yet fully proven, within the mineral lease area.

Marra Mamba ore, a mixture of hematite and goethite, is low in impurities such as silica and alumina normally associated with hematite ore of the Brockman Formation. Unlike the blue, hard Brockman ore, Marra Mamba is yellow/brown in colour, soft and friable. The ore's chemical qualities make it an extremely convenient blend material. Consequently blending will tend to extend the life of the Venture's Brockman reserves.

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During 1975 a 200000-tonne bulk sample of Marra Mamba ore was tested by various ore buyers. In 1978 a further test saw 650000 tonnes of Marra Mamba ore successfully blended with Mt Whaleback fines as a 15 per cent component.

In 1980/81 a further trial, involving the blending of 1.1 million tonnes or Marra Mamba ore is being carried out. Should the Marra Mamba-Whaleback blend find customer acceptance, a mine capable of producing up to 3 million tonnes of ore a year will be built. Six 68-tonne Haulpak trucks, two D9G bulldozers, a 992C front-end loader and a diesel-powered Bucyrus-Erie primary drill are being used during the trial period.

MAIN MINE EQUIPMENT AT JUNE 1, 1980

		No. of Units
Drills - primary	Bucyrus-Erie 60R primary drills of 310 mm	10
	Bucyrus-Erie 60R primary drills of 380 mm	3
	(1 diesel-electric, 9 all-electric)	
Drills - secondary	Boulder drills (Cat. 950)	2
Drill - ore grade	Ingersoll-Rand T4-W (140mm) Drillmaster	1
Shovels - P & H	1900E 7.6 m^3 electric	8
	2100B 9.2 m^3 electric	8
	2800B 17 m^3 electric	2
	2800B 18.5 m^3 electric	2
Haulage Trucks—WABCO		
	75B (68 tonnes)	
	Water-tankers	13
	General duty	1
	Haulage	6
	120 (109 tonnes)	53
	Model 3200 (189 tonnes)	22
Rock Breaker	Stott impact breaker	1

AUXILIARY MINE EQUIPMENT

Trucks	Fuel trucks	2
	Fuel/lube trucks	2
	Lube trucks	6
	ANFO explosive supply trucks	8
Tyred loaders and dozers	Dart D600	2
	Cat. 992B	1
	Cat. 992C	5
	Cat. 824B	8
	Cat. 824C	2
	Cat. 633D Scraper	1
	Various tractors and mini-loaders	6
Tracked Dozers	Cat. D9-G (tractors and dozers)	21
Road Maintenance	DRMCO 100-T	1
	Cat. 12E	3
	Cat. 16G	5
	Ingersoll-Rand SP60 vibrating rollers	2
Cranes	90 tonne mobile crane	1
	75 tonne mobile crane	1
	35 tonne rough terrain mobile crane	1
	30 tonne mobile crane	1
	12.5 tonne mobile crane	3
	8 tonne mobile crane	1
Mobile Workshops		4

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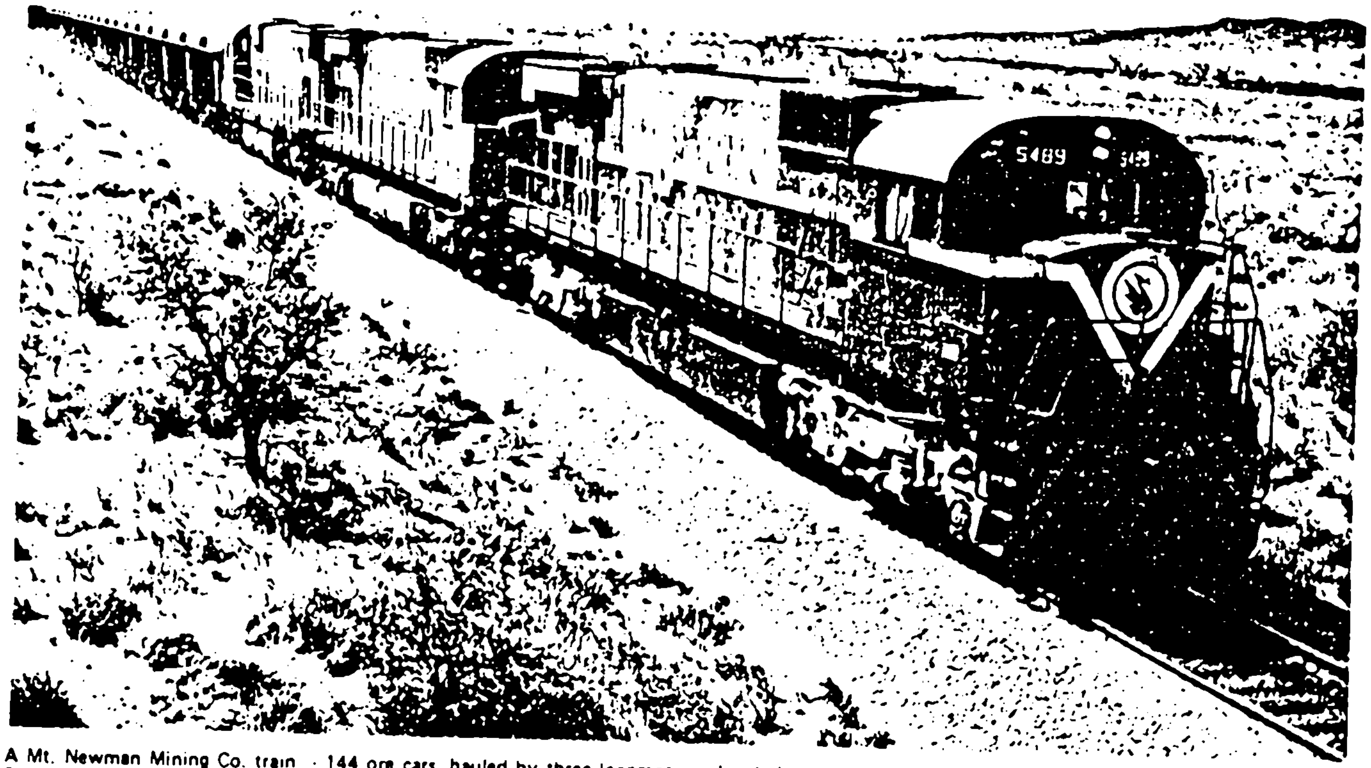

A Mt. Newman Mining Co. train - 144 ore cars, hauled by three locomotives, heads for the Mine at Newman after dumping its load 426km away, at Port Hedland. The round trip takes 19.5 hours, and there is a total of 69 trains a week every week of the year.

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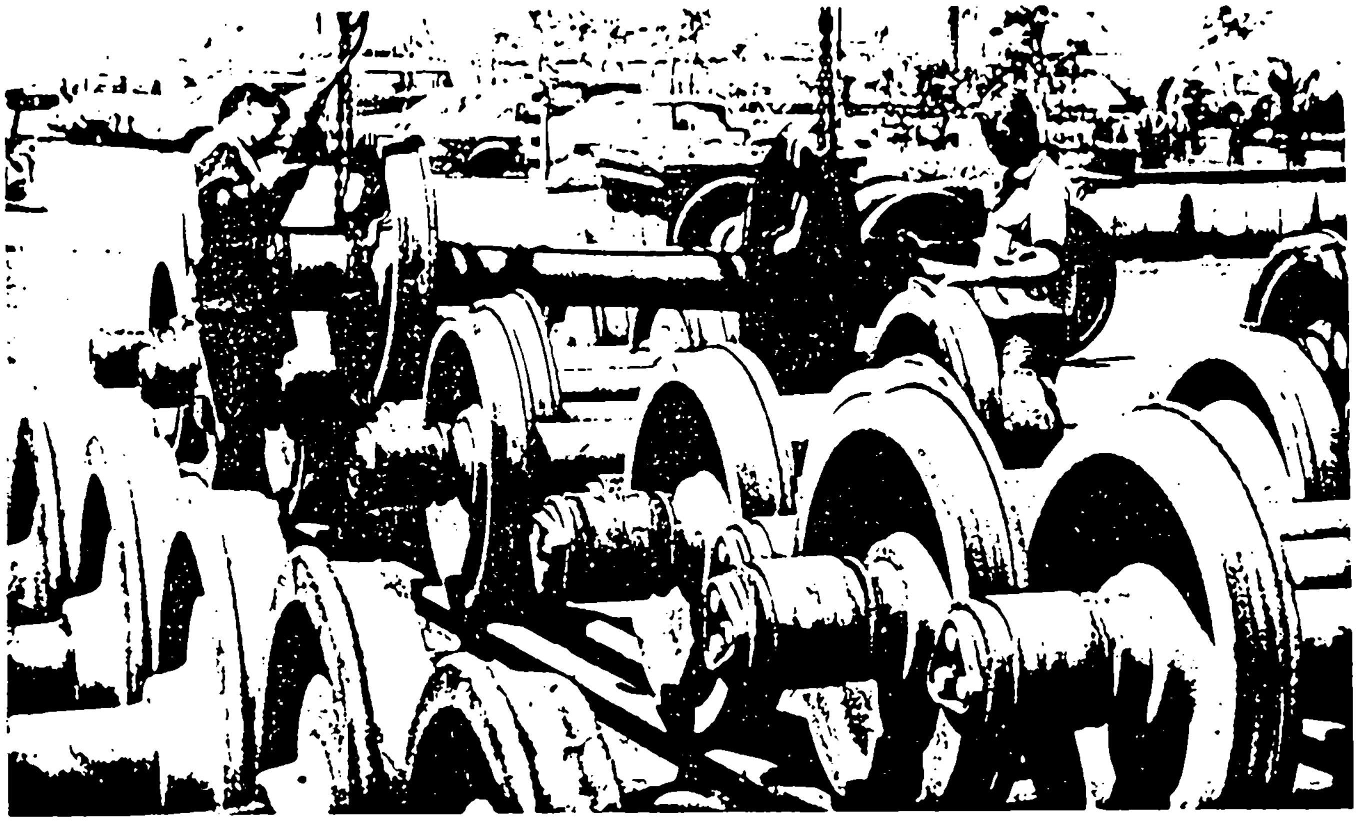

Wheel assemblies outside the ore car workshop at Nelson Point.

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Railroad operations

3

The 426 km heavy-duty standard gauge railroad between Mt Newman's Mt Whaleback iron ore mine at Newman and Port Hedland on the North West seaboard was officially opened by the then Premier of Western Australia, Sir David Brand, on January 22, 1969, after a record-breaking construction effort.

An American-Canadian joint venture, Morrison-Knudsen-Mannix-Oman, was awarded the 1970 Construction Achievement Award by the Australian Federation of Civil Engineering Contractors for building the railroad ahead of schedule and for establishing a world track-laying record.

The line was built to high standards with 440 m lengths of the heaviest rail then used in Australia. Weighing 65.5 kg/m, the rail was originally laid on 2.6 m x 228 mm x 152 mm Western Australian jarrah sleepers with centres 533 mm apart.

Some 63000 tonnes of rail and 870,000 sleepers were used in addition to 600000 m³ of high-grade granite ballast. Curvature and gradients were kept to a minimum and the most severe mainline curve is only 527 m radius. The steepest grade against the loaded train is only 0.55 per cent fully compensated.

The single-line railroad has 14 passing loops, each approximately three kilometres long. These allow loaded ore trains, which always have the right of way, to have a clear run from Mine to Port. At June 1, 1980 the railroad was handling a total of 69 trains a week. The railroad carries a greater tonnage than the entire Western Australian Government Railways system.

The length of each train is set at 144 loaded ore cars drawn by three 2680kw Alco diesel-electric mainline locomotives. A loaded train weighs approximately 18 300 tonnes of which 13 750 tonnes is payload.

Trains make the journey from the Port to the Mine and back in 19.5 hours, the outward journey taking about 9.5 hours.

At Newman 114 minutes are allowed for loading, and at the same time the train crew is changed. Actual loading of the 144-car train takes only 70 minutes. When loaded the trains head through the Ophthalmia Range at Ethel Gorge, travel westward along the Fortescue Valley for 145 km then swing north into the Chichester Range. Here the trains climb 91 m in 26 km. Over the crest the line drops 213 m in 27 km before levelling off on the coastal plain for the remaining 185 m to the Port. Trains are operated to a maximum speed of 65km/h when loaded and 75km/h when empty.

At Nelson Point, Port Hedland, spotters direct the positioning of the first two or three ore cars of each train into car dumpers. The locomotives are then uncoupled and driven into a loco servicing workshop for maintenance. The crew goes off to rest and preparation crews take over. Ore dumping takes two hours and locomotive servicing three hours. Then a new crew takes over the train and sets off for Newman.

Control of all trains rests with traffic controllers at Port Hedland manning a complex communications system 24 hours a day. The controllers are in direct contact with train crews at all times on three high-frequency radio channels relayed through eight automatic repeater stations situated approximately 56 km apart.

The controllers keep a constant record of all track activity including that of maintenance equipment, work gangs and inspection cars. They record train movements and timings by means of charts and graphs and all conversations are recorded on tape automatically.

To cope with this traffic, the port yard utilises power-operated turnouts controlled from a tower on the ore car repair shop building. From this tower, all yard operations are visible. To expedite the movement of trains on the main line, a centralised signal system, supervised by the Hedland traffic controllers, is used. The terminal for this equipment is in the railroad administration building north of the locomotive workshop.

Batteries powering the repeater stations are charged by wind generators with back-up diesel generators starting automatically if the batteries drain to less than half capacity. If the diesel sets fail to start after three attempts, they cut out and a light flashes on the supervisory panel in the radio maintenance office.

A total of 54 locomotives and 2,099 ore cars are in use and the railroad's capacity is rated at 40 million tonnes of ore per year.

Permanent way experiments involve the constant monitoring of rail-head wear and defects, development of improved techniques in rail replacement and transposition, testing of various wood, concrete and steel sleepers, and rail fastenings and rails to different metallurgical formulae. Knowledge gained from these experiments is used to improve the already high standard of track maintenance necessary for such high tonnage movements.

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Testing of steel sleepers intensified towards the end of May and in June an order for 210,000 steel sleepers was placed. These will be installed over the next three years, from 1981.

All curves of one degree or tighter will be replaced during 1980 with special head-hardened rail.

In addition to experiments on the permanent way, experimental modifications to ore cars are being tested. These tests are being carried out to lengthen time between overhauls and reduce harmful dynamic effects on the track. Experiments to obtain more data on the longitudinal dynamics of trains in motion are also in progress.

Four permanent camps are used by track maintenance personnel and track machinery service workshops are located at all of these places. A fifth workshop is located at Newman and a base workshop at Hedland.

In addition to over 90 automotive units ranging from utilities through mini-buses to a mobile workshop, a comprehensive range of earthmoving equipment is used for maintenance of railroad access roads and earthworks. Continuous maintenance of the track itself employs a fleet of 24 specialised machines.

Maintenance of locomotives and rolling stock is carried out at Nelson Point. A comprehensively equipped workshop services locomotives and overhauls are undertaken at a separate workshop. An ore car shop and underfloor wheel lathe shop are located south of the marshalling yard.

RAILROAD ROLLING STOCK AT JUNE 1, 1980

		No of Units
Locomotives	Goodwin Alco C636 2680 kw	17
	Goodwin MLW M636 2680 kw	16
	ComEng MLW M636 2680 kw	11
	ComEng MLW M636 2680 kw with Dofasco bogies	10
Ore Cars	100 tonne capacity	1,997
	90 tonne capacity	102
Tank cars	Fuel—113 650 litres	9
	81 830 litres	6
	Water—81 830 litres	4
Compressor/Index Car Sets		4
Ballast cars	38.30m³	48
Index/brake cars		4
Flat cars	137 tonnes	1
	51 tonnes	24
	35 tonnes	3
Box car	50 tonnes	1
Trackmobiles		4
Breakdown car		1
Scale test car		1
Locotrol car		1
Passenger car		1
Side dump cars		4

TRACK MAINTENANCE MACHINERY

Mainline tamping machines	2
Switch tampers	1
Crib consolidator	2
Mono rail tamper	1
Ballast regulator	2
Speno rail grinder	2
Rail laying/recovery train	1

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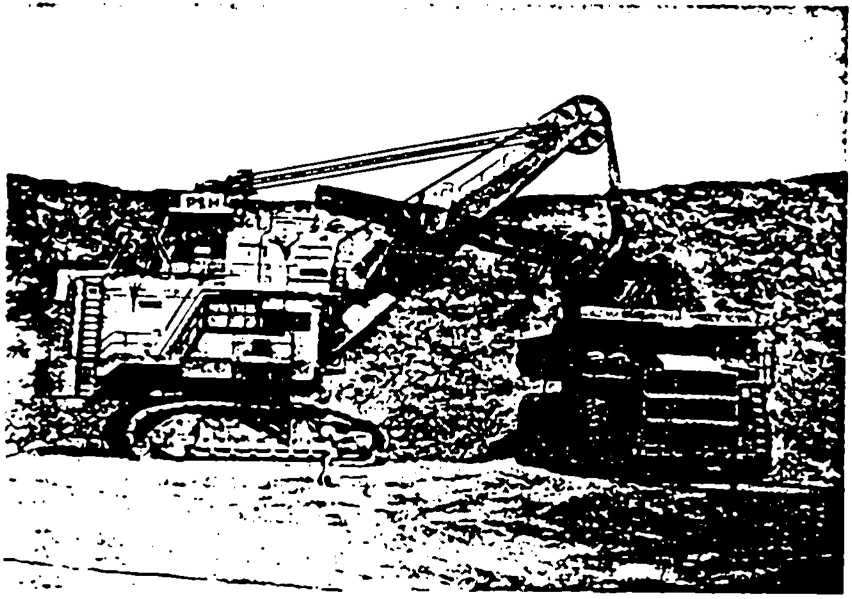
GENERAL RAILROAD STATISTICS

Length of mainline track including mine loops:	430 km
Length of passing loops:	41 km
Length of yard sidings and marshalling tracks:	94 km
Rail: 66 kg/metre continuously welded rail, mostly standard carbon steel.	
Mainline sleepers: Treated hardwood/steel	2.6 x 225 x 150/2.6 x 300 x 1.2
Crossing timbers: Treated hardwood	varies x 225 x 175

Turnouts: 1 in 15 mainline and 1 in 10 yard. Two 1 in 20 mainline swingnose, power-operated.
Rail fastenings: Pandrol on steel baseplated with cut dog spikes on the timber sleepers and Pandrol and Tracklock on the steel sleepers.
Ballast: Crushed granite to A.R.E.A. No. 4 grading 250 design depth, modified A.R.E.A. No. 3 ballast.
Ruling grade: Against loaded 0.55, against empty 1.50 per cent.
Axle loading: 30 tonnes.
Bridges: 26 high level, nine low level.
Culverts: 627 locations, mostly corrugated galvanised steel.
Signals: Controlled signals, 104, automatic signals, 65, mainline points machines, 82, track circuits, 247.
Radio communications: 3VHF channels covering the whole track from eight repeater and two terminal stations over a multiplex UHF bearer.
Ground communications: 420 kilometres of private, unsealed access road.
Air: Four permanently-maintained light aircraft strips in addition to Port Hedland and Newman airports.

P & H 2800 series shovel loading waste into 200 -tonne Haulpack, exposing working face of high grade iron ore.



Dave McMeeken, an ore handler at Newman watches the monitors which tell him how the ore is moving through the Beneficiation Plant. He can control the whole plant through the panel, linked to a computer.

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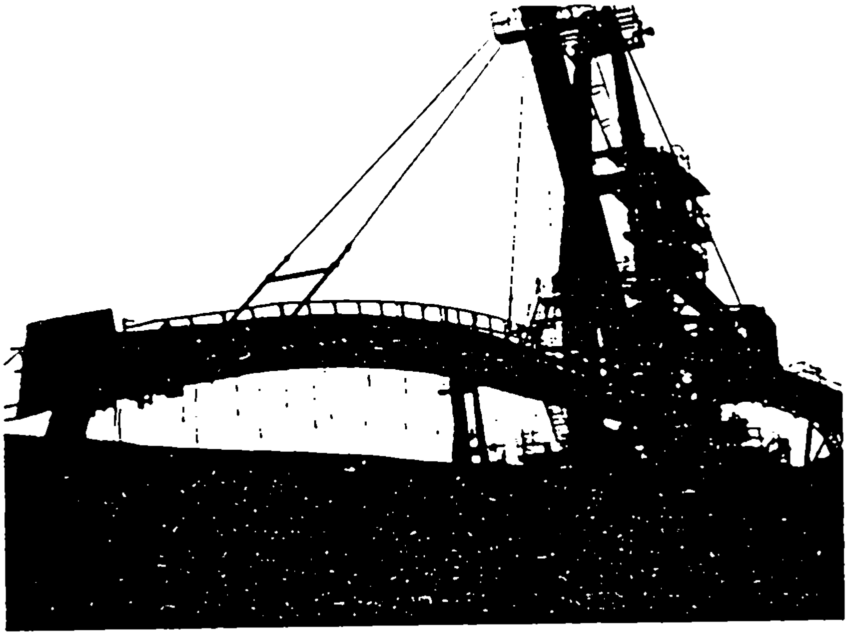
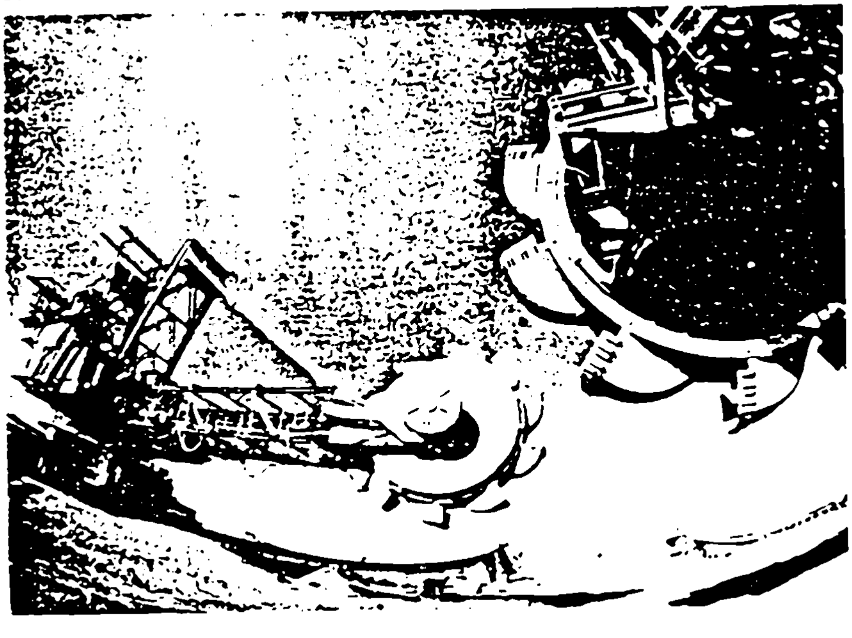


A rail mounted boom stacker feeds the stockpile at Nelson Point.

Bucket wheel reclaimers retrieve ore from the stockpiles to begin the shiploading sequence.



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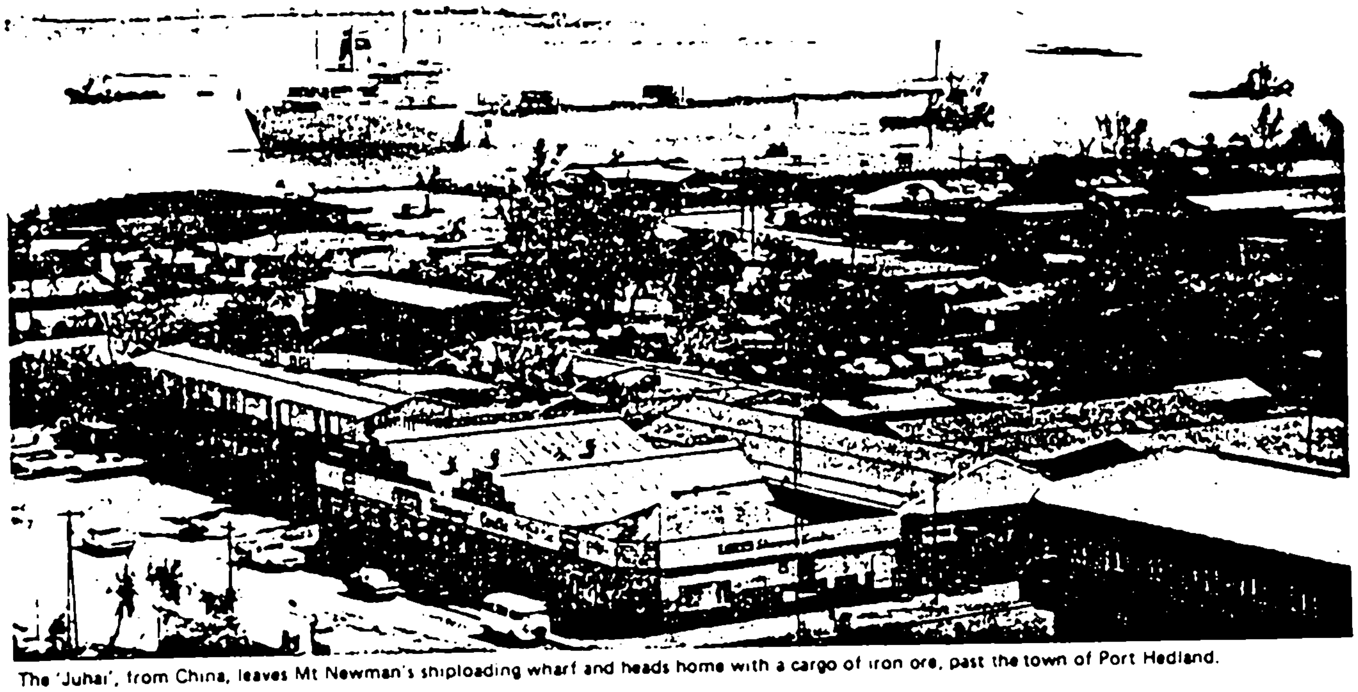

The 'Juhai', from China, leaves Mt Newman's shiploading wharf and heads home with a cargo of iron ore, past the town of Port Hedland.

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

Port operations

4

Mt Newman's operations have helped to transform Port Hedland from a tidal port restricted to ships of less than 5000 deadweight tonnes into the biggest exporting port in Australia in terms of tonnage throughput. Today, Port Hedland is one of only a few ports in the world capable of handling 180000 deadweight-tonne ore carriers.

Operations at Nelson Point, Port Hedland, are divided into two areas. The first covers the unloading of trains, crushing of iron ore to final shipping sizes and stockpiling. The second involves reclaiming ore from the stockpiles and loading it into vessels. A major expansion programme completed in 1976 added a second dumping, crushing and screening plant which lifted total annual production capacity to more than 40 million tonnes.

CAR DUMPING

Trains from the mine at Newman are positioned to unload ore in either of two car-dumping complexes at Nelson Point. Both dumpers are of McDowell Wellman rotary design, the ore cars being fed in by an electric winch-type car-positioner.

The No. 2 Car Dumper, rated at 10500 tonnes per hour, tips three cars at a time through 135° to empty their loads into surge bins below. The positioner arm then indexes the next three cars into the rotary cells and the unloading operation repeated within a 104-second cycle time. Rotary couplers allow the cars to remain coupled to the rest of the train during the unloading operation.

A 375 kw DC electric winch, driving through two sets of 65 mm wire ropes, gives the positioner a maximum rated arm force of 104 328 kg. Coupled with a modern solid state converter drive system, this has the excellent control characteristics needed for accurate and fast positioning of trains of up to 240 cars. During the positioner return cycle, the cars are locked in position by three sets of hydraulically-operated scissor-type wheel-locks, each with a holding capacity of 22000 kg.

The dumper cells are rotated by a solid state, converter-fed 37 kw DC motor, coupled via a gearbox and pinion to flange-mounted ring gear. As they rotate, counterweight-actuated car clamps hold the cars within the assembly.

From three 1 220 tonnes live capacity surge bins below the No. 2 dumper, the ore is fed by electro-magnetic vibratory feeders to a conveyor rising from 19.4 metres below ground level to a transfer station 30.6 metres above ground. A "splitter" in the transfer station divides the ore into two streams. One stream, of approximately 7500 tonnes per hour, is fed to the No. 1 Crushing and Screening Plant. The second stream, of 3000 tonnes per hour, is fed to the No. 2 Crushing and Screening Plant.

The operation of the original No. 1 Car Dumper is similar to that of the No. 2 system except that two cars only are tipped in a 92.5 second cycle and conventional motor generator sets are used to power the winch and dumper drives.

TERTIARY SCREENING AND CRUSHING

In the original No. 1 Screening and Crushing Building ore is fed from 12800-tonne capacity surge bins to 18 Allis Chalmers 6 m x 2.34 m double-deck screens. Ore of -30 mm to +6 mm is screened off as lump product and -6 mm ore is separated as fines product. Ore over 30 mm is crushed by nine Allis Chalmers hydrocone crushers and re-circulated to the surge bins for re-screening.

To achieve accurate quality control and maximum throughput it was decided to separate screening and crushing functions, and incorporate an advanced computer-control system in the No. 2 Ore Handling Plant. This was commissioned on September 23, 1976. The concept produced a plant featuring a computer-controlled Screening Building, with tripper-fed surge bin having 8800-tonnes capacity. From this surge bin ore is fed to eight Allis Chalmers 6 m x 2.43 m double-deck screens, where it is separated into lumps (-30 to +6 mm) and fines (-6 mm). These products in turn are fed to a Crushing Building where a 750-tonne capacity surge bin supplies three Allis Chalmers Hydrocone Crushers.

The computer-control system continuously monitors ore flow, bin levels and trends, equipment availability and so on, with the ability to automatically start or stop equipment as required by programmed parameters of throughput and quality control.

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

The No. 2 Ore Handling Plant incorporates modern working conditions and extensive ventilation and dust-collection systems. The design also allows for mechanised clean-up, using small loaders.

From the screening and crushing plant part of the ore goes to sampling stations for quality control checks before being reunited with the main ore stream conveyor belts serving boom stackers for stockpiling.

STOCKPILING AND RECLAIMING

Four rail-mounted boom stackers, designed by McDowell Wellman Engineering and fabricated in Western Australia by Vickers Hoskins Pty Ltd., feed lump ore (-30 mm + 6 mm) or fines (- 6 mm) to stockpiles. Each stacker can handle 4000 tonnes an hour. Operators, working in air-conditioned cabs 12 m up the 27 m stacker frames, build up stockpiles by lowering or raising the 48 m booms through their reach from ground level to 12.5 m as the stackers move up and down the track. The booms can also be slewed across a stockpile.

Two crawler-mounted bucketwheel reclaimers and two rail-mounted reclaimers start the shiploading sequence. Each 530-tonne crawler reclaimer, designed and built by Demag Lauchhammer of West Germany, has 10 buckets on a 7 9 m diameter wheel and is capable of digging 3000 tonnes of ore from a stockpile in an hour. The buckets empty ore through conveyors on a 14 m long boom and a 26 m discharge boom at the rear into a self-propelled hopper car. When a reclaimer is working on a stockpile location where its discharge boom is beyond the reach of the hopper car it feeds ore into a mobile transfer station, called a bandwagon. The bandwagon and hopper car then feed ore onto a 770m reclaim conveyor belt running the length of the stockpile area.

The rail-mounted bucket wheel reclaimers are 915-tonne structures each capable of recovering and discharging ore at an average rate of 6000 tonnes an hour through a chute and impact table. Among the biggest reclaimers in the world, these were designed by Demag Lauchhammer and fabricated by Vickers Hoskins. Ten buckets are set on a 10 4 m diameter wheel on each unit. Each reclaimer is self-propelled, mounted on 42 wheels, and can be slewed through 360 degrees.

At the end of the reclaim conveyor belts, an automatic sampling station scalps off samples of up to 270 kg for assaying at a pre-determined frequency of up to once every 1000/1250 tonnes. The ore is transferred to a conveyor system along the two-berth ore pier or into two trim bins which act as a storage facility while the shiploaders move from one hatch to another or from one ship to another.

SHIPLOADING

Each of the two rail-mounted shiploaders supports a hinged telescopic boom which feeds the ore into a bulk carrier's hold at a rate of up to 8130 tonnes an hour. Two carriers can be loaded simultaneously or both shiploaders can operate on one carrier.

The 658 m two-berth ore pier is the only facility in Australia capable of berthing and loading two 160000 deadweight-tonne bulk carriers at the same time. The No. 1 berth is at the intial pier, a 352 m structure made up of 423 piles driven to bedrock and capped with a concrete decking 330 mm thick. The No. 2 berth is at a 306 m long extension. An approach trestle, 97 m long, connects the pier with the shore.

The pier is divided into three sections. The first, the transfer platform, is 30 m wide. On it stands the transfer station linking the pier with the shore. The second section is the tripper platform, 23 5 m wide, which transfers ore from the conveyor to the shiploaders. The third section is the ore-loading platform, 25.6 m wide, along whose two-berth length the shiploaders can travel

Protecting the pier and mooring dolphin are Raykin fender panels made up of 305 mm jarrah beams connectd to a steel framework and to Raykin rubber overloader fender units. These panels are designed to withstand the breasting forces of a heavy tonnage iron ore carrier moving sideways on to the pier at 5.5 m a minute. The pier deck is 10 1 m above Admiralty datum, the standard low-water mark. Tides at Port Hedland range between 0 4 m above Admiralty datum to 7 7 m above.

Developing Port Hedland into Australia's biggest export tonnage harbour and giving it the capability of handling 160000 deadweight-tonne ore carriers up to 305 m in length involved dredging more than 21 4 million m^3 of material from the harbour bottom and entrance channel. A channel approximately eight nautical miles, or 14.5 km long, 11 8 m deep and 183 m wide in the straight section, widening to 244m on curves, leads to an inner harbour channel, 11 8 m deep and 244 m wide.

Adjacent to the Mt Newman ore pier is a turning basin 914 m long, 610 m wide and 8 14 m deep. Alongside the pier are two berths, each 17 1 m deep and each capable of accommodating a fully-loaded 160000 deadweight-tonne ore carrier. Tug services are provided by the Adelaide Steamship Co. Limited under an agreement that company has with Mt Newman Mining and Goldsworthy Mining.

Industrial facilities at Nelson Point include administration offices, general and electrical workshops, a power station with an output of 22.5 megawatts, warehouse, railroad workshops and loco maintenance sheds, railroad and port control offices, a sample preparation building and assay laboratory, changerooms, and lunchroom facilities.

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AUXILIARY PORT EQUIPMENT AT JUNE 1, 1980

		No. of Units.
Dozers:	Cat. D9G	2
	Cat. D6B	1
Graders:	Cat. 12E	1
Front-end loaders:	Cat. 950	2
	Cat. 814	1
	Cat. 824	1
Clark Bobcat 825.		3
Mobile cranes	Manitowoc 140-tonne	1
	P & H hydraulic 35-tonne	1
	BHB 8-tonne	1
	BHB 5-tonne	1
Kenworth water tanker:	35 000-litre capacity	1
C-Pull water tanker:	35 000-litre capacity	1
Ford general purpose tractor 4.500		2
Fiat general purpose tractor 540		1
McDonald Johnson roadsweeper		1

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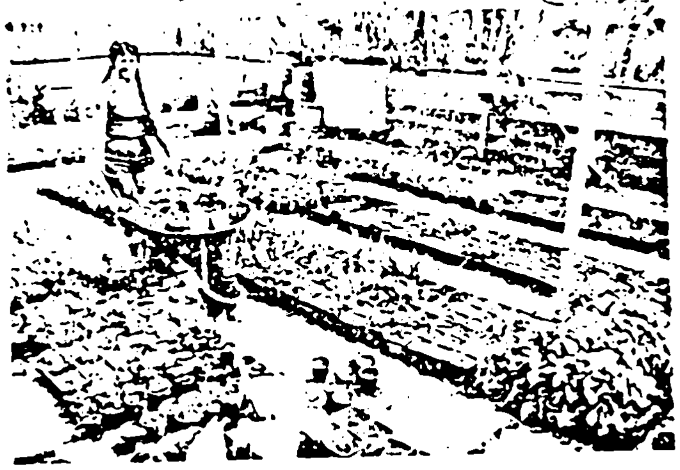
Interior of one of the modern, air-conditioned homes at Newman

Lunch at the Newman Single Persons' Quarters' Mess



The plant nursery ensures a supply of plants and trees for Newman gardeners

EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

Housing and amenities

5

Development of Mt Newman's iron ore mining operations has helped to transform the North-West of Western Australia. At March 31, 1980, Mt Newman employed 3862 people — 187 at its Perth Office, 2018 at Newman and 1657 at Port Hedland. Forty-six nationalities were represented in the workforce at Newman and Port Hedland, Australians accounting for 55 per cent of the total. British people, including Scots and Welsh, were second on the list followed (in numerical order) by New Zealanders, Yugoslavs, Irishmen, Germans, Swedes, Danes, Indians, Italians, Poles, French, Chileans, Turks, Canadians, Malaysians, Singaporeans, Burmese, South Africans and Egyptians and smaller groups of other nationalities.

Daily jet flights to and from Perth and modern housing and community facilities provided for employees and their families at Newman and Port Hedland have removed the sense of isolation once associated with the North-West.

HOUSING POLICY

Mt Newman's housing policy has been framed to meet the needs of employees and the operational requirements of the Mt Newman Iron Ore Project alike. It is based not only on a commitment to provide modern, well-serviced housing for its employees but also on the belief that "company town" precepts are no longer relevant to the now well-established progressive areas in which the Company operates.

Accordingly, the policy places emphasis on married and family housing and private boarding facilities for single people and young adults with less dependence on single person's accommodations. Single Persons' Quarters housing, particularly that providing short-term or transitory accommodation, will always be needed but the Company sees this as part of a comprehensive housing programme and not as the basis of one. In October 1979 Mt Newman introduced its "Home Ownership Scheme" and since then till June 1, 1980, a total of 100 homes at Port Hedland and 127 at Newman were being signed up under the scheme. Mt Newman believes this approach is helping to mould a better balanced community enjoying not only the amenity of a normal, multi-base town but the ambience of one.

All accommodation is fully air-conditioned and a nominal rent is charged. This varies according to the type of accommodation and, for single people, covers full board. At Port Hedland, power for air-conditioning is free but normal State Energy Commission charges are applied for household electricity used. All houses and flats are furnished and a 380 litre refrigerator and electric stove are supplied. An automatic washing machine is also provided except in some flats which have block laundry facilities.

NEWMAN

The town of Newman, 1030 km north of Perth and 6 km east of Mt Whaleback mine, was established by the Venture in 1968 and has a population of more than 5,600. Residents live in 978 houses, 336 flats and 571 units for single persons. Of the houses, 37 are owned by contractors or Government departments. A caravan park, self-contained with its own shop and manager's house, has been established south of the town to accommodate 100 caravans. An additional 75 houses will be finished by December.

The three and four-bedroom houses and one and two-bedroom flats, set in tree-lined streets, skirt community facilities on two sides with three blocks of two-storey Single Persons' Quarters on the third side. Landscaped gardens surround a shopping centre, town office and Single Persons' Quarters and dining centre. Residents take pride in their gardens and Newman's reputation as the "cleanest, greenest town in the North West"

Amenities include a modern 24-bed hospital, medical centre and dental clinic, St. John Ambulance centre, pre-school centre, two primary schools and a senior high school taking students to Years 11 and 12. Community needs are met also by a recreation club, youth club, community hall, recreation centre, supermarket and shopping centre, hotel, drive-in cinema, bank, bakery, laundry and a wide range of services. Residents enjoy live colour television and direct dialling telephone services and an all weather airport, serviced by daily jet flights, which puts Newman within 95 minutes flying time of Perth.

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Newman's sporting facilities include a golf course, two swimming pools, two grassed sports ovals, squash court, floodlit tennis and basketball courts, hockey field, clay target and rifle and pistol ranges. Sporting clubs formed by residents also cater for football, cricket, motor sports, go-karting, gliding and a variety of other activities. Women's organisations are active within the town. An attractive picnic area has been developed at Gingianna Pool between Newman and the airport.

Situated 546 metres above sea level, Newman has an attractive climate. The March to September cool season, when many varieties of wild flower cover the surrounding hills and plains, is particularly enjoyable. The summer season, between October and February, brings temperatures which are frequently above 37.8° Celsius but it is a clear, dry heat, tempered by seasonal winds and cool evenings.

PORT HEDLAND

At Port Hedland, Mt Newman employees and their families are housed at Cooke Point, an attractive seaside suburb developed by the Venture 4.8 km east of the town. Here, they are accommodated in 218 houses, 124 flats and 570 units for single persons.

Mt Newman has also built extensive housing at the suburb of South Hedland which is being developed within four centres. Its seven-storey block of 72 apartments in the first centre, providing occupants with two and three bedroom accommodation, is the tallest building north of the Tropic of Capricorn in Western Australia. Within the four centres, Mt Newman has built 245 houses, 343 cluster-type homes, 84 flats and 72 apartments. An additional 35 houses were under construction at South Hedland at June 1, 1980.

Mt Newman has contributed substantially to Port Hedland's community development, providing an infant health centre, recreation club and an Olympic-size swimming pool — and a major contribution to the shire's population.

Reserves and geology

6

The Mt Newman deposits are in a mineral lease covering nearly 800 square kilometres. The prime orebody, Mt Whaleback, is a hill 5.5 km long and 225 metres high in the Newman area of the lease which covers part of the eastern end of the Ophthalmia Range. To the north-west is the Weeli Wolli area covering deposits in the extreme eastern end of the main Hamersley Range around Weeli Wolli spring. To the south-west of this reserve is the Conndawanna area, south of Mt Robinson.

At Mt Whaleback, outcropping hematite ore discovered in 1957 by veteran prospector Stan Hilditch assayed at 68.8 per cent iron content compared with a possible maximum of 70 per cent pure hematite ore. Seven months of drilling in 1963-64 indicated the presence of at least 220 million tonnes of hematite ore averaging 64.6 per cent iron.

Subsequent mapping and drilling through to 1972 proved the presence of more than 1 400 million tonnes of high-grade ore, making Mt Whaleback one of the largest single deposits of hematite ore in the world. At June 1, 1980, a total of 269 million tonnes of ore had been mined and shipped since the start of operations in 1969.

An active exploration programme over the mineral lease areas has located 40 orebodies of varying sizes within five to 60 kilometres of Mt Whaleback. Their total potential is estimated at between 5000 and 6000 million tonnes of ore of various grades.

GEOLOGY

Mt Whaleback is probably the richest deposit in the great Hamersley Iron Province which starts at the coast north of Onslow and runs east-south-east for more than 500 kilometres. The province contains vast quantities of iron-bearing material, an estimated 24000 million tonnes of which contains more than 55 per cent Fe.

The province includes the Hamersley and Ophthalmia Ranges which are formed mainly by the Brockman Iron Formation — a 600 metre thick layer of banded iron formation (laminated rock consisting of alternating layers of iron oxide and chert). An older iron formation, some 150 metres thick, also occurs in the area — the Marra Mamba Iron Formation. This usually has poor outcrop and is seen as low, rounded hills paralleling the main range.

The Brockman Iron Formation is much harder than the surrounding rocks and erosion of these softer rocks over millions of years has resulted in the spectacular hills and gorges in iron formations such as Mt Bruce, Wittenoom and Dales Gorges.

In many places, particularly towards the south of the province, the 2,000 million-year-old formations have been distorted into complex folds, then partly eroded to leave scattered residual hills. Over the period, orebodies have formed by the silica in the iron formation being gradually dissolved and carried away by percolating groundwaters.

The iron formations throughout the province usually have a 25 per cent to 35 per cent iron content. In Mt Whaleback, one of the most spectacular examples of enrichment of Brockman Iron Formation, the ore zone consists of high grade hematite averaging up to 69 per cent Fe but it also includes a number of interbedded shale bands which reduce the ore body's average grade to 63.7 per cent Fe. The ore has been formed by the replacement of silica and other gangue minerals by secondary hematite.

The ore in Mt Whaleback extends from one end of the hill to the other in a band usually about 120 metres thick but often thicker because of folding. It extends downwards as deep as 35 metres below the general plain level.

Several major ore types have been recognised within Mt Whaleback ranging from hard, dense, massive hematite to hard, porous, banded hematite. The hard, porous, blue hematite — prized by steelmakers — predominates. The ore is low in impurities and has impressive metallurgical characteristics. Impurities such as copper, sulphur, chromium, vanadium, nickel, tungsten, lead, bismuth, arsenic, tin, and molybdenum — all of them troublesome to the steelmaker — occur in minor quantities of less than 0.01 per cent.

Among the known Pilbara iron ores, the Mt Whaleback ore has the best ratio of silica to alumina. Most customers favour a minimum 2:1 ratio but this is rarely achieved with high-grade Pilbara ores. The average for Mt Whaleback ore is, in general, even more favourable. This factor, combined with a low phosphorus content, gives the Mt Whaleback ore its widely sought-after characteristics.

In addition to Brockman Iron Formation ores, Mt Newman has proven reserves of about 500 million tonnes of Marra Mamba Formation high grade ore including approximately 460 million tonnes immediately adjacent to the Mt Whaleback mine and with more favourable stripping ratios than the Mt Whaleback operation. Apart from these proven reserves, the Mt Newman lease carries additional extemely large quantities of Marra Mamba ore, both high grade and low grade. It has been estimated there is an additional 500 million tonnes, at least, of high grade Marra Mamba ore, yet to be proven, in the ground in the Newman area. Unlike the Brockman Iron Formation ore from Mt Whaleback, the Marra Mamba ore is yellow/brown in colour, soft and friable.

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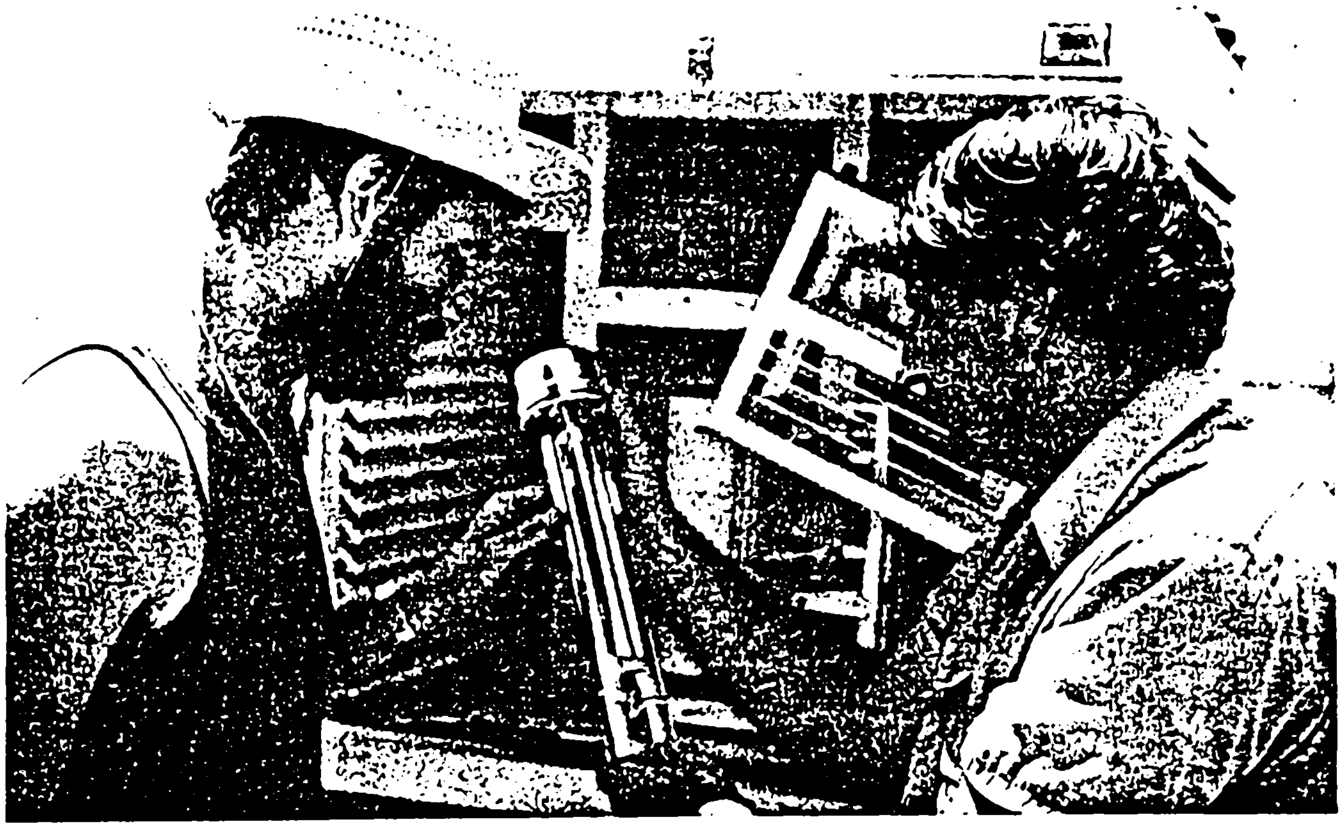

Environmentalists keep close watch on the effects iron ore mining has on the Newman and Port Hedland areas.

Environmental programme 7

Mt Newman is actively pursuing an environmental policy aimed at improving living and working conditions in its operational areas while conserving natural ecosystems that may be influenced by Company developments.

The policy is formulated through an Environmental Committee which meets regularly to initiate, review and co-ordinate programmes. This body received advice from a consultant, Professor D. O'Connor of the Department of Environmental Studies at Perth's Murdoch University.

Mt Newman's Environmental Department has two major roles. The main one is promotion of an awareness of environmental problems and means by which Company departments can co-operate and solve them. Also a wide range of studies are initiated drawing on many research groups.

Plant life has been surveyed on undeveloped ore bodies by the Western Australian Department of Agriculture Herbarium using infra-red photography. The Department of Agriculture is assisting the Company develop the best approaches to rehabilitating abandoned mine benches and waste dumps. It is also providing expertise for coastal dune revegetation in conjunction with the Office of the Regional Administration of the North-West.

A fauna survey conducted for the company by a leading Western Australian naturalist has recorded the many species of birds and animals thriving in the area.

At Port Hedland biologists have studied harbour life as part of an on-going research programme. The results of these studies will enable Mt Newman to take immediate remedial action if adverse effects of the operation are observed.

Local and overseas consultants have been involved in a major water conservation study at Newman involving surface and groundwater aspects. Also a number of projects are underway to re-use waste water generated from plant operations.

The Company has engaged the Western Australian Museum to investigate potential ore body locations and areas where ground disturbance is likely. This is to ensure that Aboriginal sites or artefacts are not damaged or accidentally destroyed.

At Port Hedland a major climatology study has recently been completed and as a result a computer model of the area's atmospheric conditions has been produced. This will enable the Company to plan further expansion programmes with minimal air-quality effects for the adjacent communities.

Dust sampling programmes are conducted regularly at both the Mine and Port, some of these in conjunction with the State Mines and Public Health Departments. Data from these programmes have been utilised to redesign plant in order to minimize dust exposure.

An extensive haulroad reticulation system has been installed at Mt Whaleback to provide effective dust suppression. Programmes are also being developed to control dust generation from non-road areas at both the Port and Mine.

The Company has also introduced a hearing conservation programme which seeks to prevent unnecessary noise induced hearing losses among its employees. The programme utilises fulltime trained audiometrists and a large number of engineers specially trained in noise measurement and control.

The widest possible range of environmental studies is being carried out by Mt Newman so that any adverse effects of its operations will be rapidly recognised and minimised.

<u>EXHIBIT "21"</u> Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980

Location, and flow diagram

[illegible] Mt Newman Mining [illegible] workshop

The East Pit gouged out by man and machine to supply the world's steel mills with raw feed from Western Australia's Pilbara region

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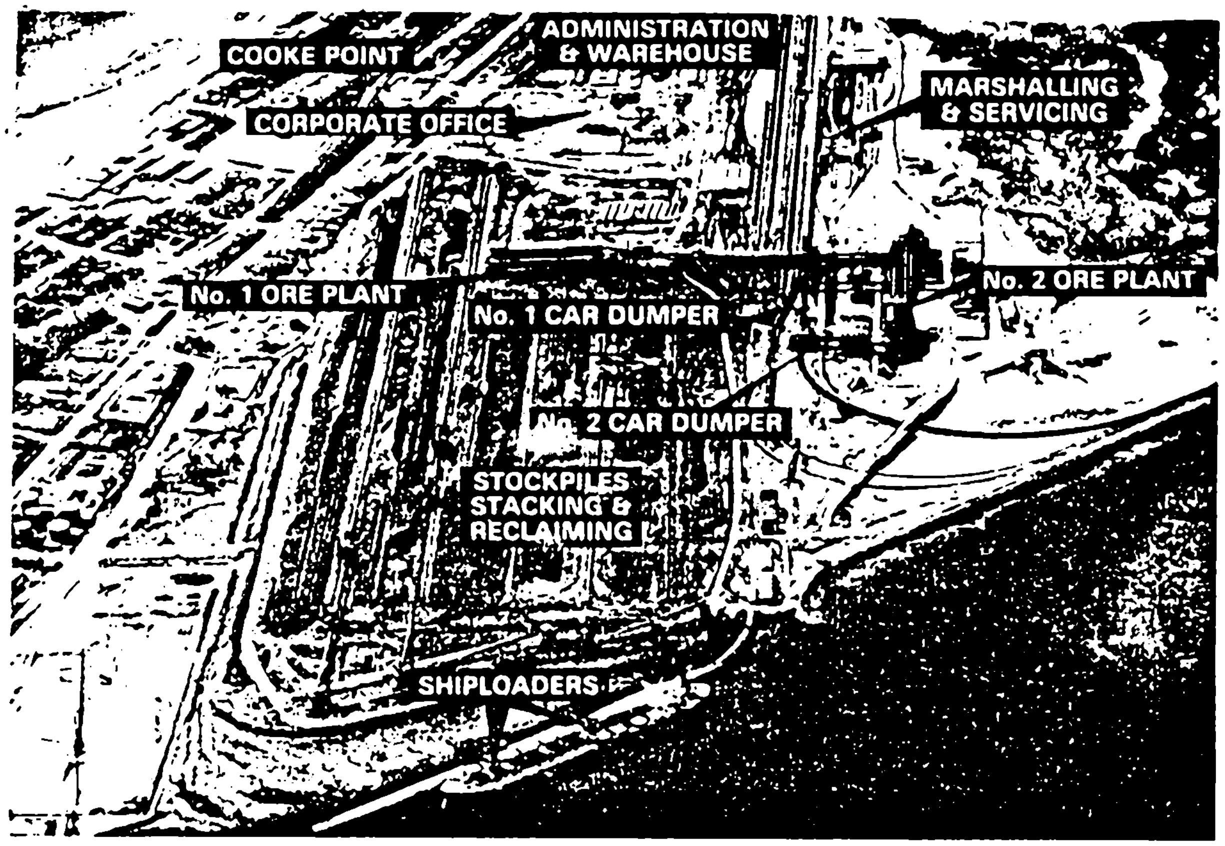

❑ PORT FACILITIES

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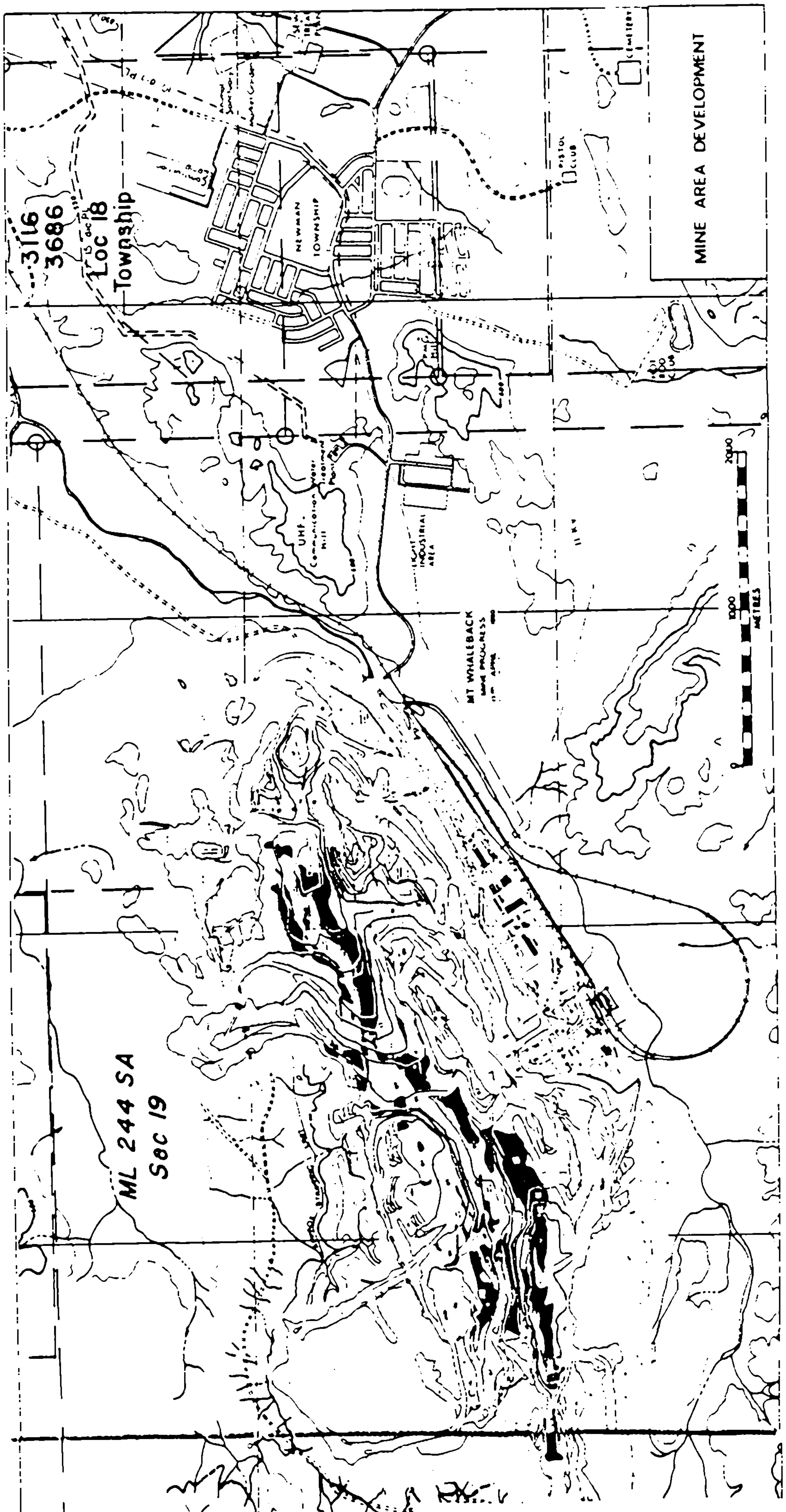

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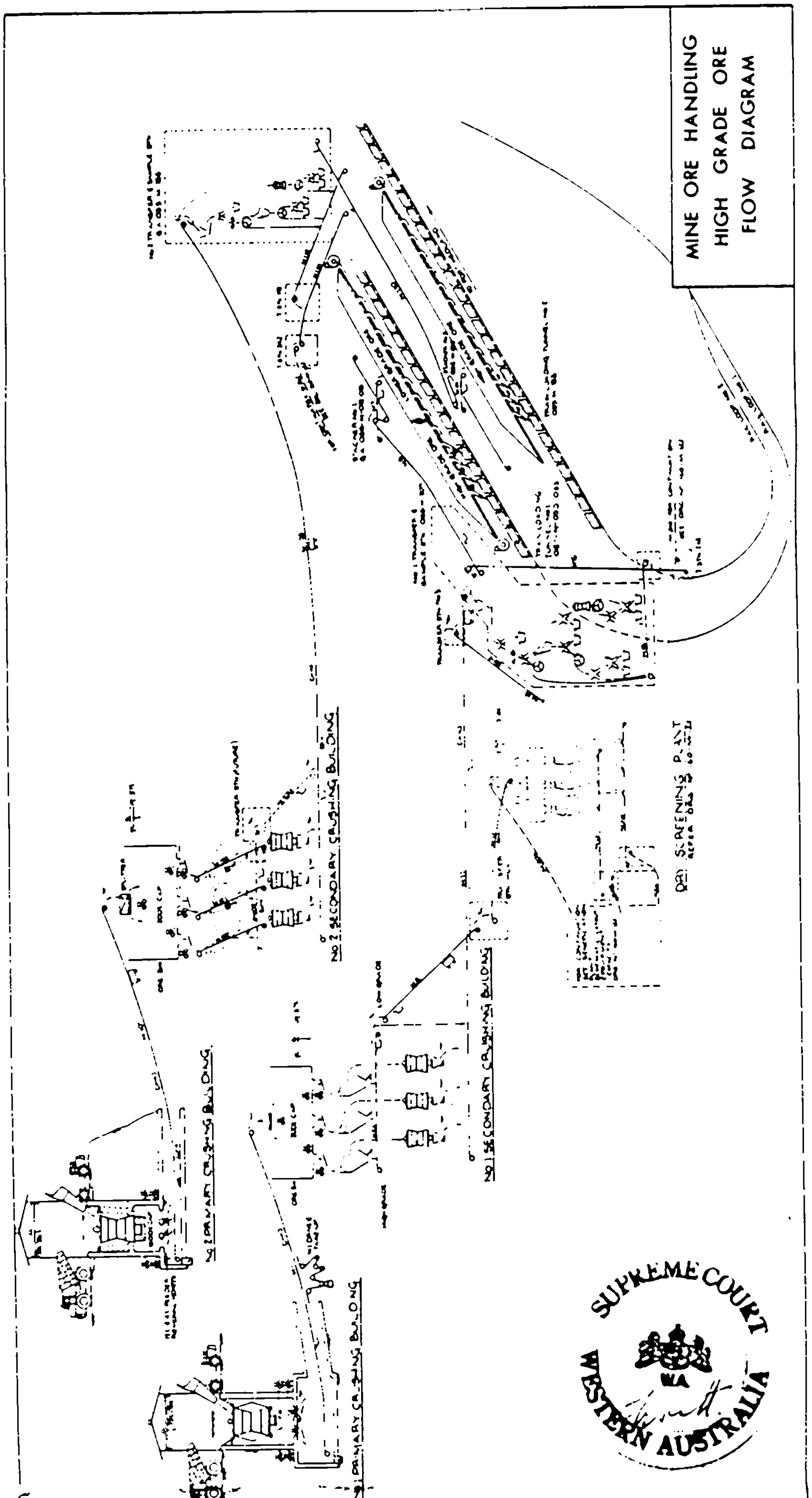

MINE ORE HANDLING
HIGH GRADE ORE
FLOW DIAGRAM

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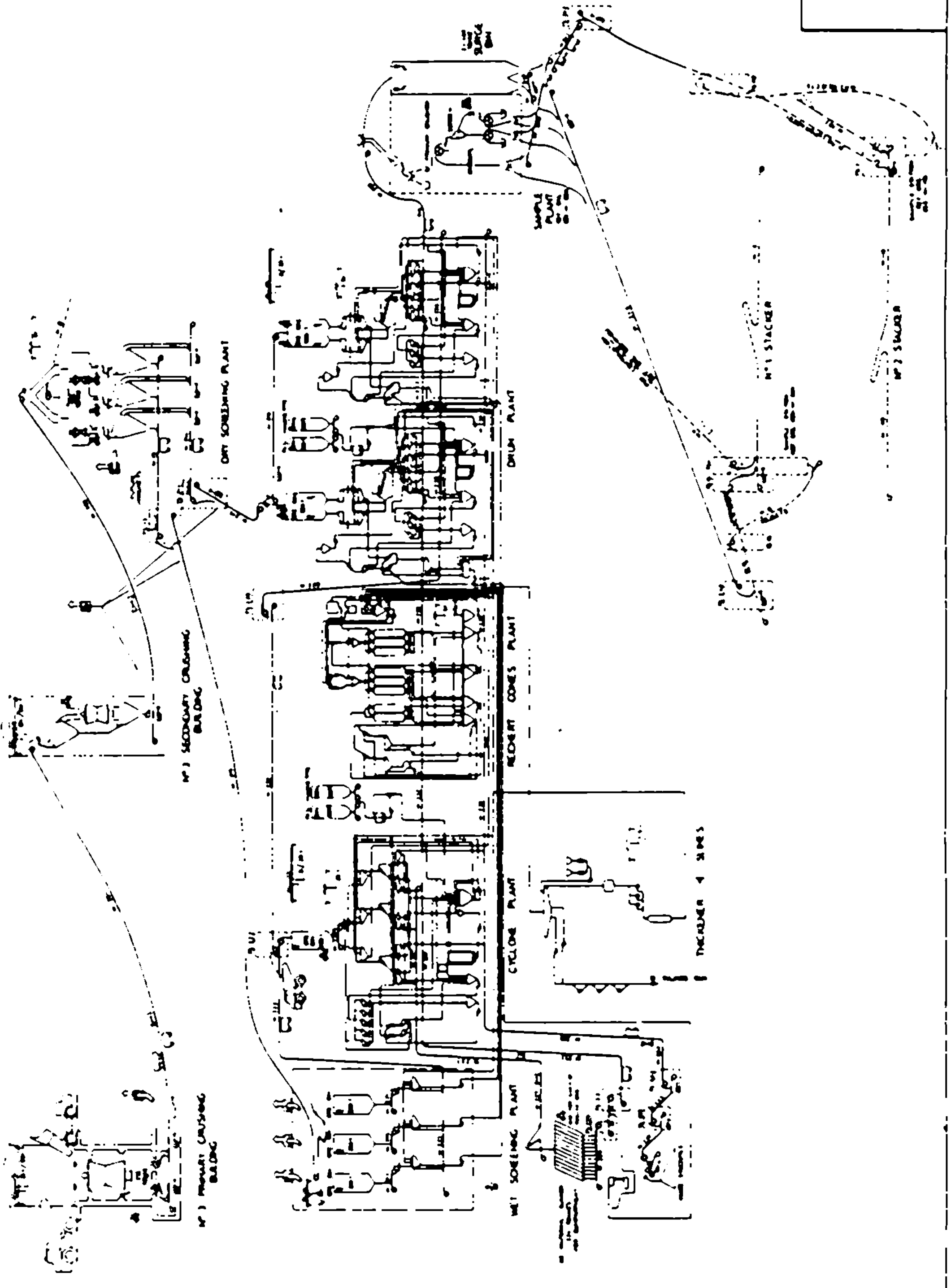
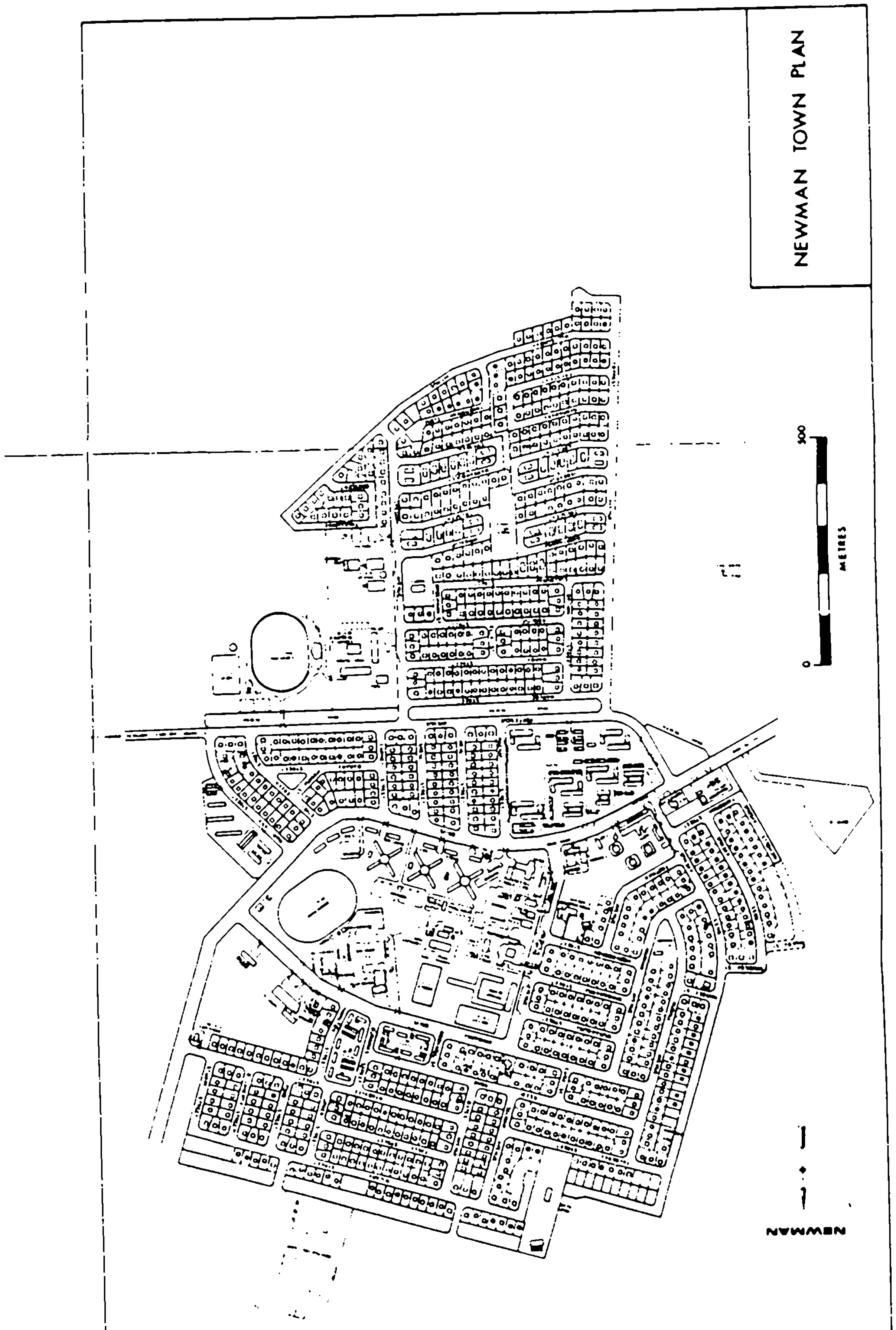
MINE ORE HANDLING
LOW GRADE ORE
FLOW DIAGRAM



1575 EXHIBIT "21" Booklet by Mt Newman Mining Company entitled "Mt Newman Operations Guide" 1980



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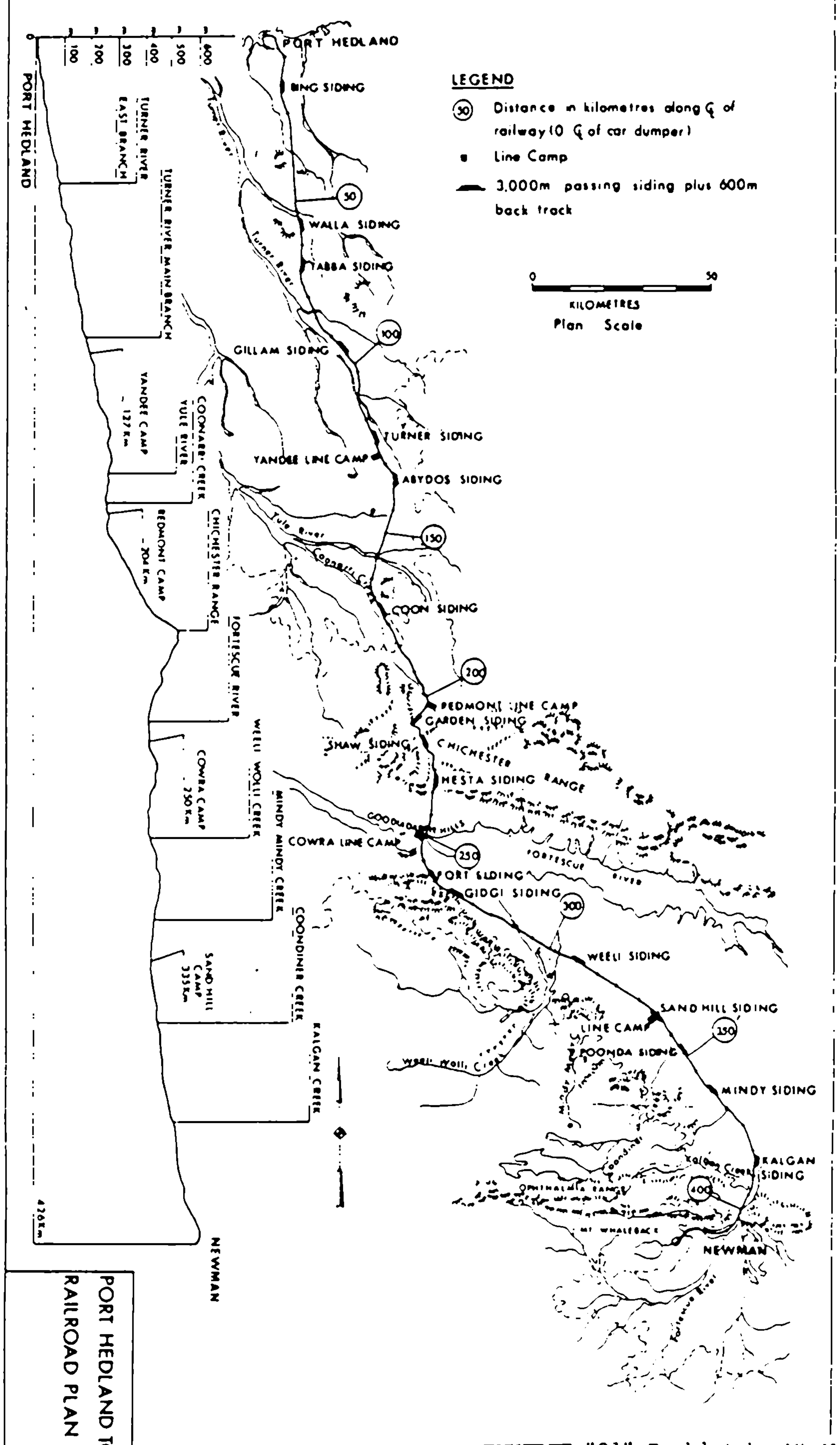

PORT HEDLAND TO NEWMAN
RAILROAD PLAN & PROFILE

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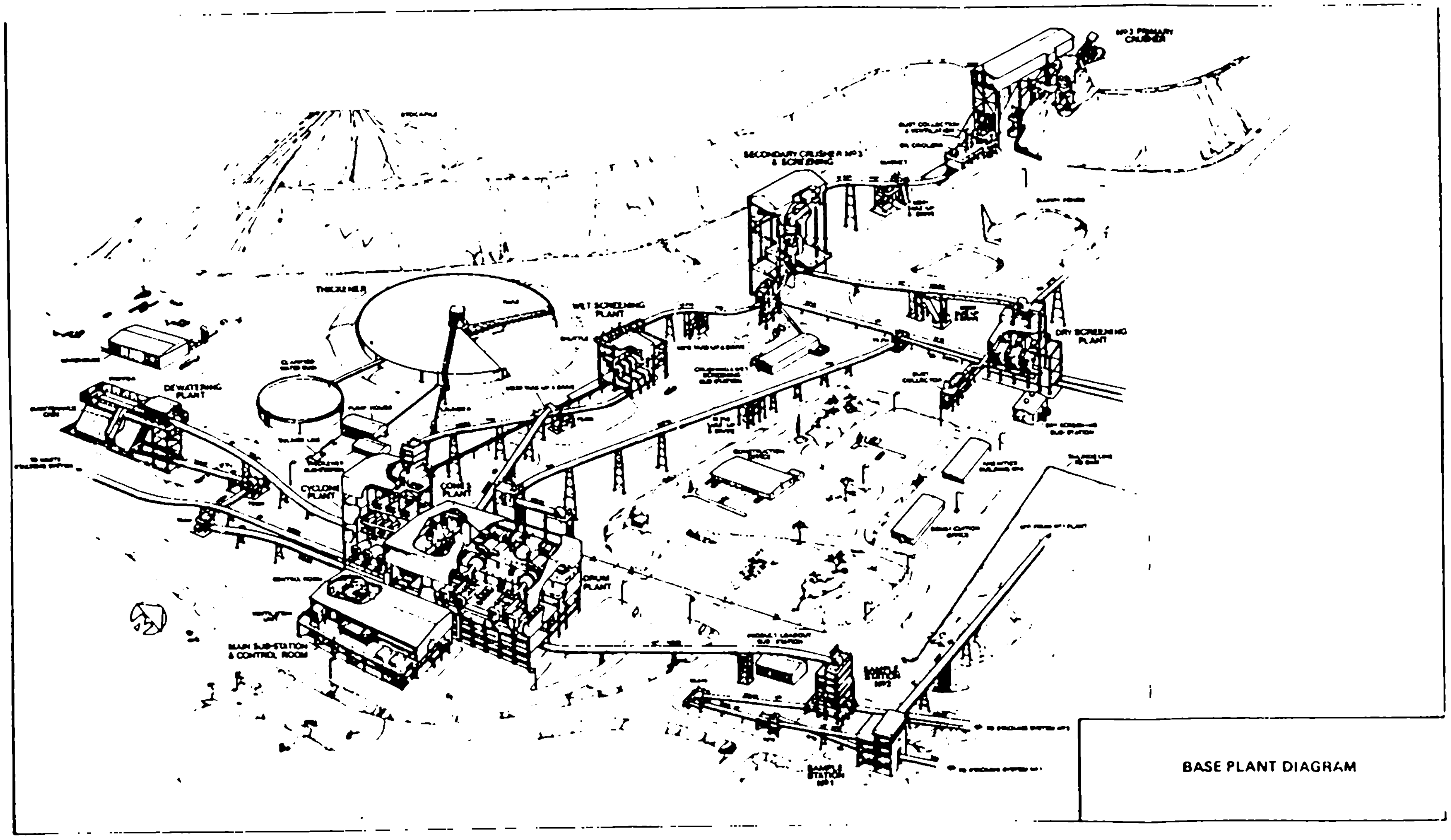

BASE PLANT DIAGRAM

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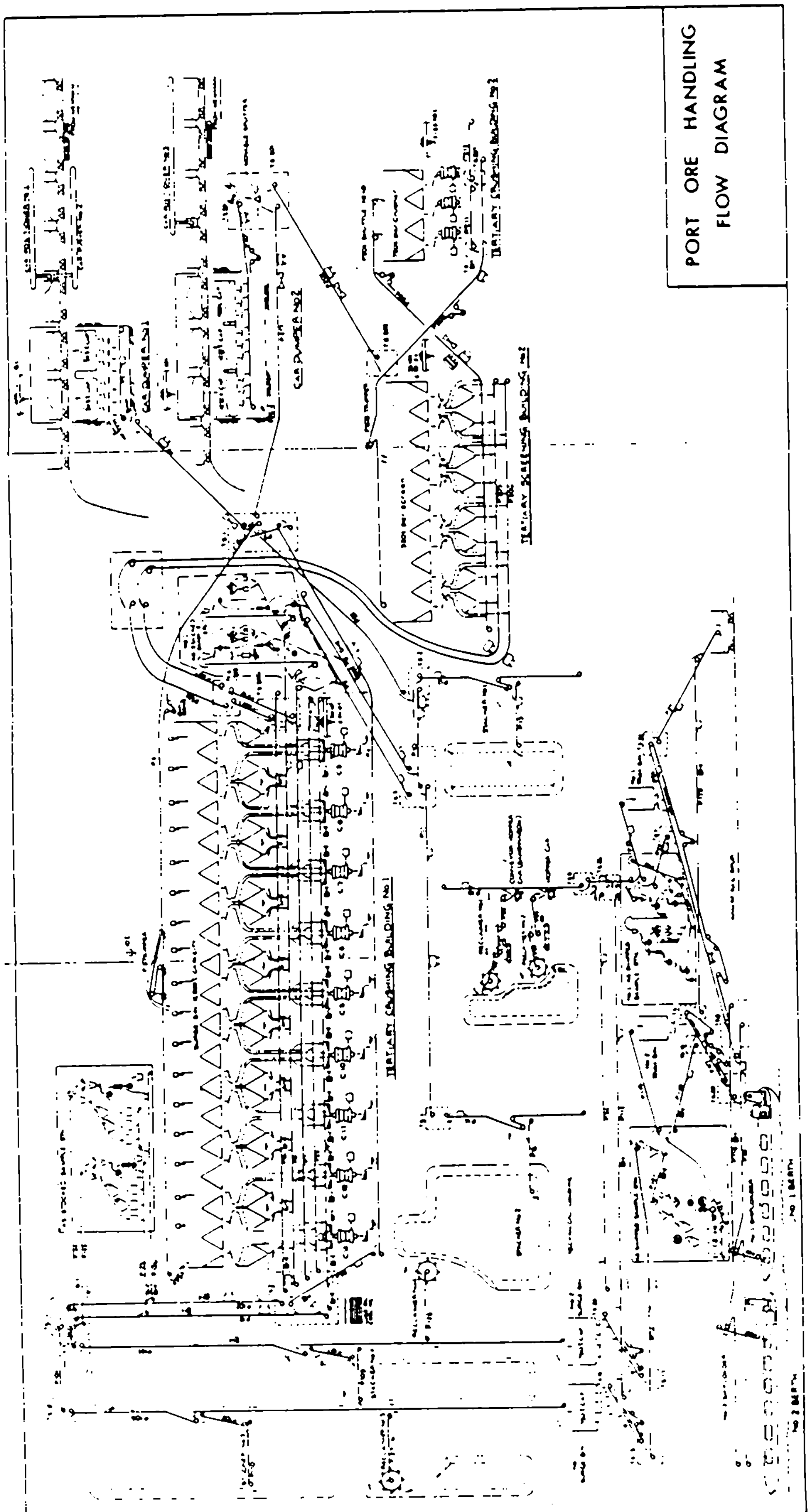
PORT ORE HANDLING FLOW DIAGRAM



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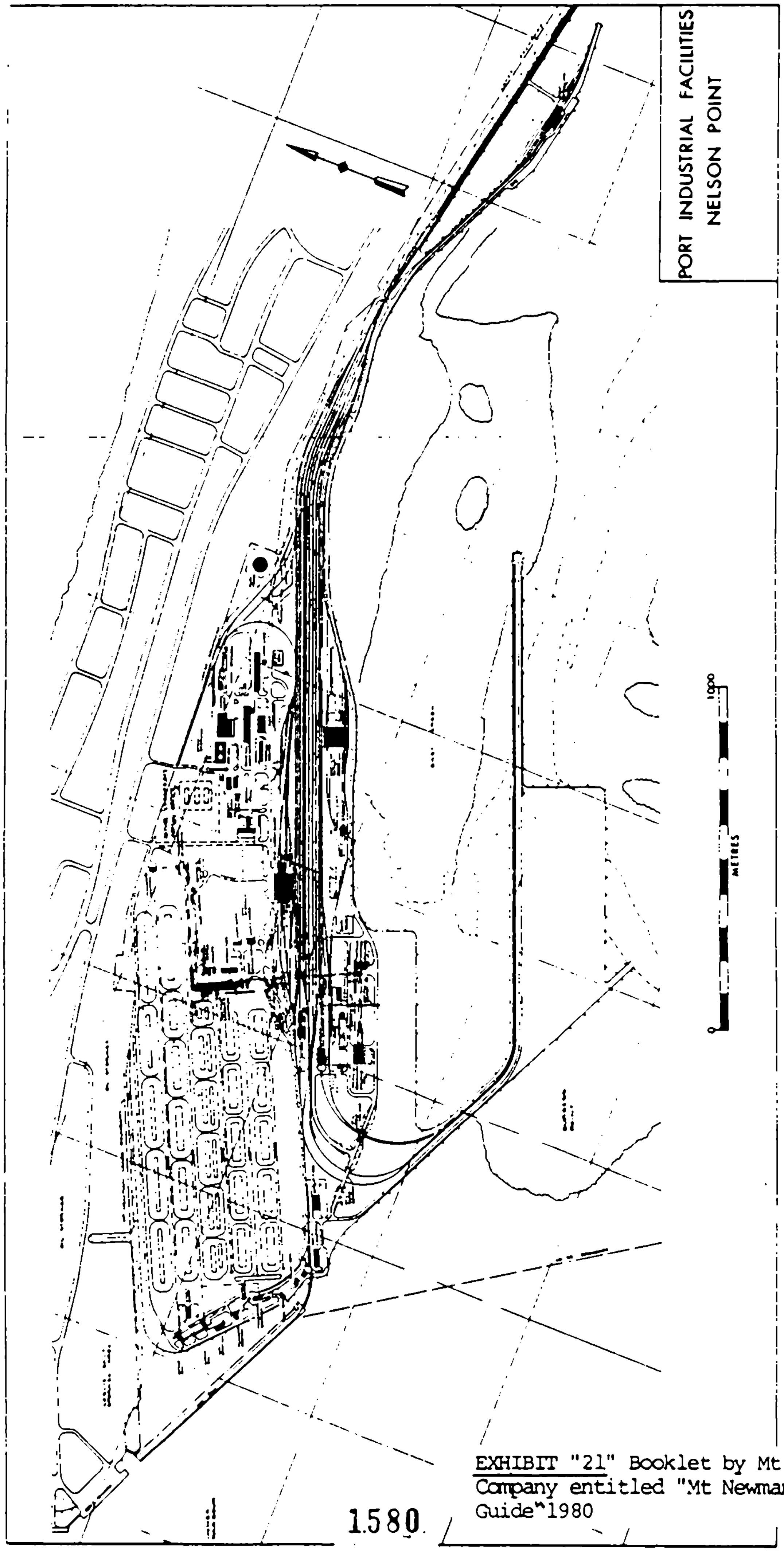

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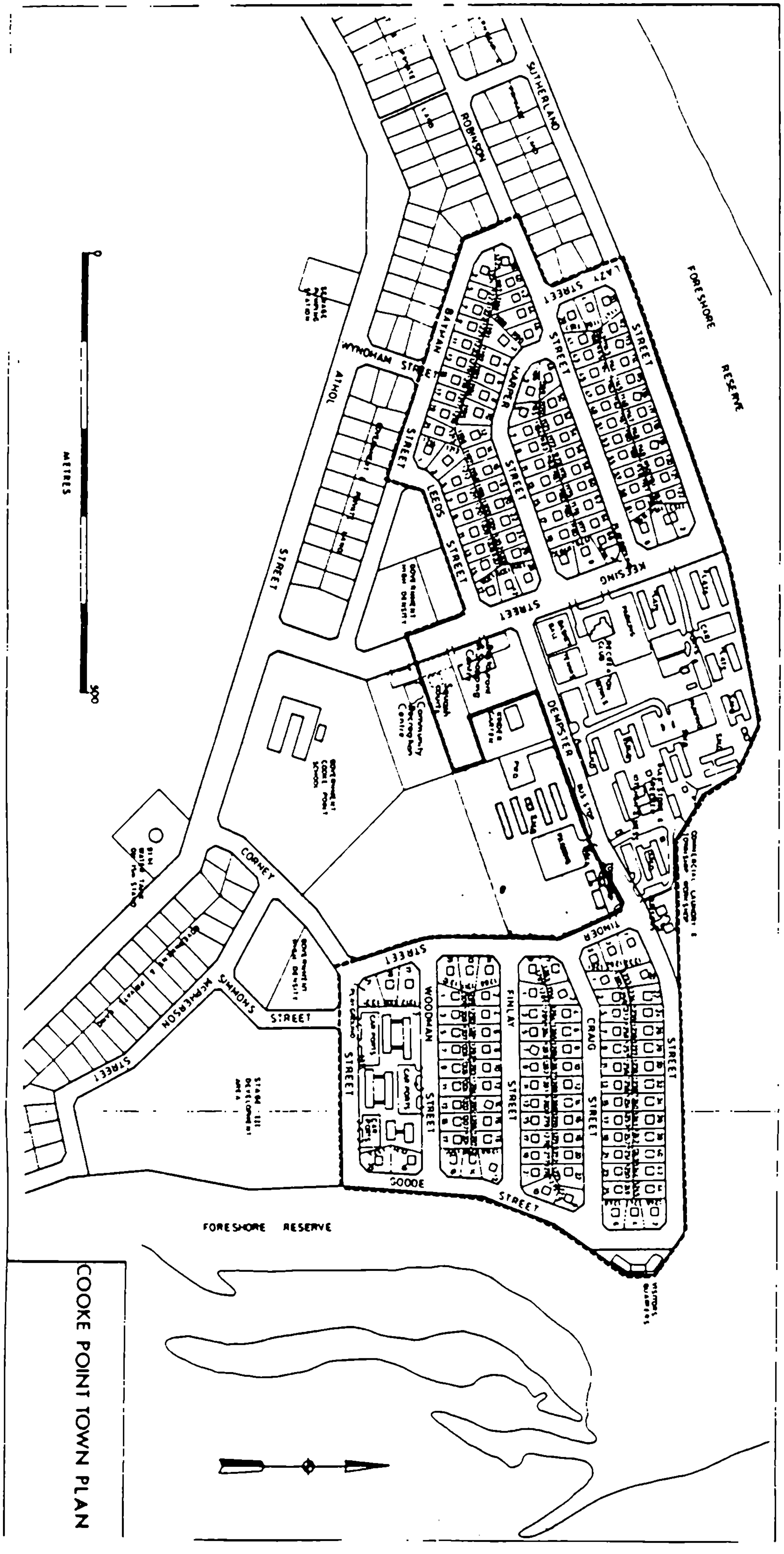

COOKE POINT TOWN PLAN

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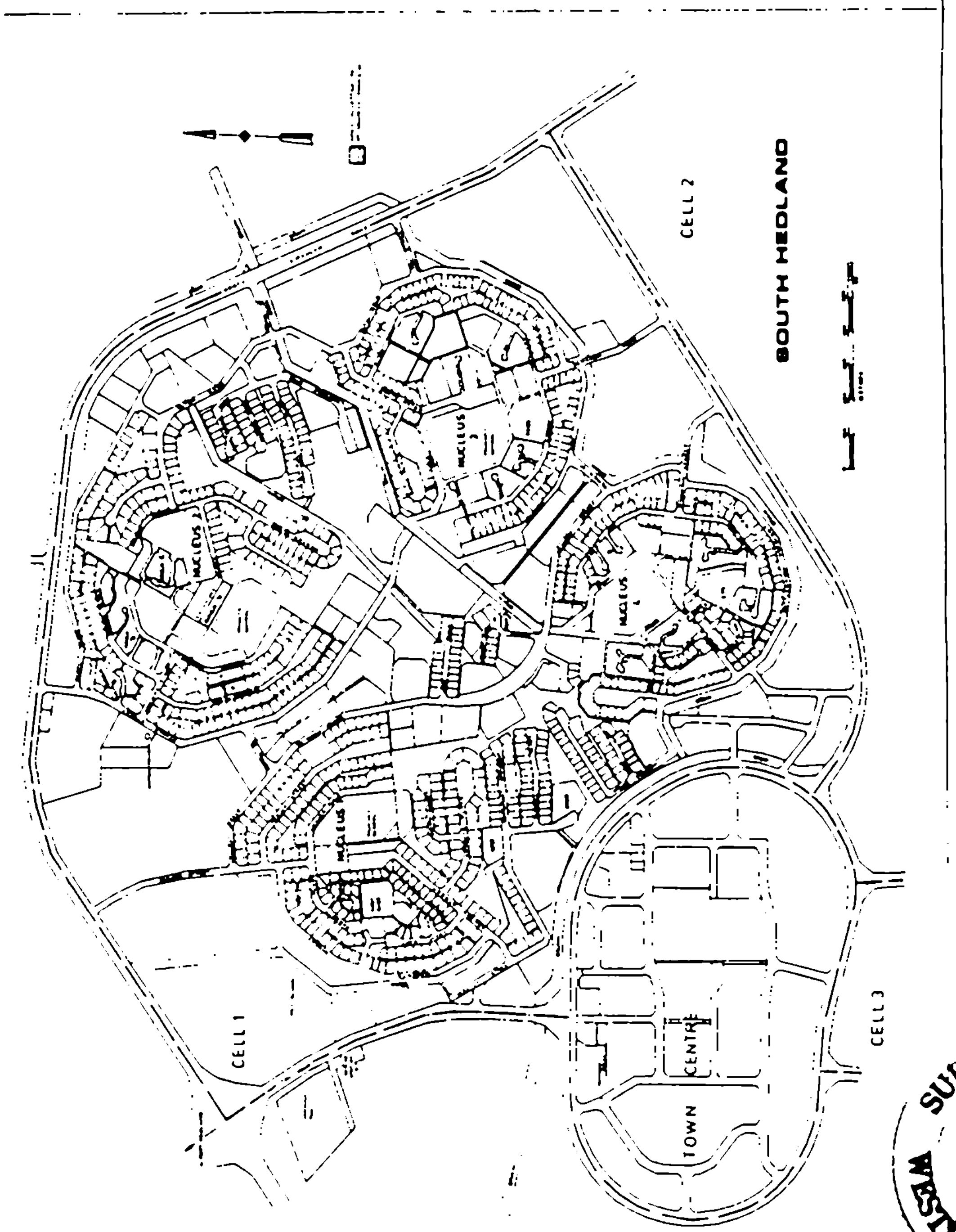
SOUTH HEDLAND
TOWN PLAN



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IN THE SUPREME COURT

OF WESTERN AUSTRALIA

No. 2313 of 1982

EXHIBIT "22" - Affidavit of Robert George Horseman dated 29.8.1983

IN THE MATTER of an Agreement between LANGLEY GEORGE HANCOCK, ERNEST ARCHIBALD MAYNARD WRIGHT, WRIGHT PROSPECTING PTY. LTD., HANCOCK PROSPECTING PTY. LTD, two other companies and HAMERSLEY IRON PTY. LIMITED

BETWEEN:

HAMERSLEY IRON PTY. LIMITED	Plaintiff
AND	
LANGLEY GEORGE HANCOCK	First Defendant
ERNEST ARCHIBALD MAYNARD WRIGHT	Second Defendant
HANCOCK PROSPECTING PTY. LTD.	Third Defendant
WRIGHT PROSPECTING PTY. LTD.	Fourth Defendant
L.S.P. PTY. LTD.	Fifth Defendant
THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED	Sixth Defendant

AFFIDAVIT

I, ROBERT GEORGE HORSEMAN of 16 Norman Street, Fig Tree Pocket in the State of Queensland, Mining Consultant, make oath and say as follows:

1. (a) I hold a Diploma of Mining Engineering from the School of Mines, Kalgoorlie (1943), a First Class Certificate of Competency as a Colliery Manager (New South Wales) and a First Class Certificate of Competency as a Metalliferous Mine Manager (New South Wales) and I am qualified as a Registered Mine Surveyor and a Registered Mine Electrician. I have been a New South Wales Examiner for Colliery Managers' Certificates and between 1979 and 1981 I was a Queensland Councillor for the Australian Mining Industry Research Association.

(b) From 1944 until my retirement in 1982 I was employed by the Broken Hill Proprietary Co. Ltd. ("BHP"). I joined BHP in Kalgoorlie in 1944 and spent time there and at the town of Iron Knob in South Australia as a supervisor gaining general experience in BHP's iron ore mining operations. (In 1944 the iron ore deposits near Iron Knob in the Middleback Ranges were the only source of BHP's iron ore for its blast furnaces at Newcastle, Port Kembla and Whyalla.) From 1945 to 1948 I was stationed at Yampi Sound as a mining engineer responsible for the construction of BHP's mine, ore preparation, ore loading and other facilities at Cockatoo Island.

(c) From 1948 to 1953 I worked at BHP's coal operations in the Newcastle area and from 1953 to 1967 I was Colliery Manager at the John Darling Colliery at Belmont, New South Wales. In both places coal production was entirely for iron and steel making operations and during that period I gained broad familiarity with iron ore properties, characteristics and preparation processes and industry usage and terminology.

(d) In 1967 I was transferred to BHP's Head Office in Melbourne to fill the position of Executive Officer, Raw Materials Department, which involved organising the supply of iron ore to BHP's blast furnaces. I made frequent visits to BHP's mines and ore treatment facilities in the Middleback Ranges and at Koolyanobbing and Cockatoo and Koolan Islands in Western Australia. I was also responsible for COORDINATING the supply and preparation of manganese from BHP's manganese ore mine and treatment plant at Groote Eylandt and coal from BHP's collieries and other coal suppliers and visited these installations too in the course of my duties.

(e) From 1969 to 1971 I was Assistant Director, Mineral Exploration and during that time visited all the iron ore mines then operating in Western Australia. From 1972 to 1976 I was the Executive Director of Mount Newman Mining Company Pty. Ltd., the

<u>EXHIBIT "22"</u> - Affidavit of Robert George Horseman dated 29.8.1983

management company responsible for the operations of the Mt. Newman joint venture. In that capacity I frequently travelled overseas on marketing missions to Japan and technical appraisal visits to Europe, North America, Africa and South America where I visited iron ore mines and processing facilities.

(f) From 1976 to 1982 I was General Manager in Queensland of Theiss Dampier Mitsui Coal Co. Ltd. ("TDM") controlling their operations and marketing activities. TDM is a producer of coal which is sold to the Japanese Steel Mills. Since my retirement in 1982 I have been regularly undertaking consultancy work for Mitsui & Co. (Aust) Ltd. 1

2. I have been asked to advise the Plaintiff in relation to these proceedings and I have read and ask leave to refer to the Affidavits of Colin Roy Langridge sworn on 2nd September, 1982 and 24th May, 1983, the Affidavit of Niles Earl Grosvenor sworn on 27th October, 1982, the Affidavits of Peter Forbes Booth sworn on 27th October, 1982 and 30th June, 1983, the Affidavit of Christian Frederick Beukema sworn on 22nd June, 1983, the Affidavit of Alban Jude Lynch sworn on 22nd May, 1983, the Affidavit of Arthur Noel Pritchard sworn on 24th May, 1983, the Affidavit of Desmond Evered Wright sworn on 30th May, 1983, the Affidavit of Douglas Frederick Tompsitt sworn on 24th May, 1983 and the Affidavit of Robin John Batterham sworn on 25th May, 1983 all filed herein. I have also examined the exhibits (other than samples of feed) to each of those Affidavits, including the Agreement which is "Exhibit CRL 1". I inspected the Plaintiff's facilities at Tom Price on 11th August, 1983. 2

3. I depose, from my own personal knowledge of industry usage in Australia both in 1962 and now, that the process described in paragraph 9 of Mr. Langridge's first Affidavit would not have been described in 1962 and would not be described now just as "screening". Spraying the ore with large quantities of water and tumbling it in the pulping box and on the screens is a cleaning process usually described as "washing". It is designed to achieve results quite distinct from those obtainable or 3

EXHIBIT "22" - Affidavit of Robert George Horseman dated 29.8.1983 expected from mere sizing. According to industry usage the processes were and are "washing and screening". I therefore agree with the opinions of Dr. Lynch, Mr. Pritchard and Dr. Batterham to the effect that the first place where a process of beneficiation (other than crushing or screening) takes place is in the pulping box.

4. I also agree with Mr. Pritchard's statement that water is an expensive and complicating component. In my experience it is not added unless a result unobtainable by simple sizing on screens is required.

SWORN by the said ROBERT)
GEORGE HORSEMAN at Brisbane)
in the State of Queensland.)
this 29th day of August)
1983.)

Before me:

A Justice of the Peace

Filed on behalf of the Plaintiff.

EXHIBIT "22" - Affidavit of Robert George Horseman dated 29.8.1983

IN THE PRIVY COUNCIL NO. 28 of 1985

ON APPEAL
FROM THE COURT OF THE SUPREME COURT OF WESTERN AUSTRALIA

BETWEEN:

HAMERSLEY IRON PTY LIMITED
Appellant
(Respondent)
(Plaintiff)

- and -

1. THE NATIONAL MUTUAL LIFE ASSOCIATION OF AUSTRALASIA LIMITED,
2. LANGLEY GEORGE HANCOCK,
3. ERNEST ARCHIBALD MAYNARD WRIGHT,
4. HANCOCK PROSPECTING PTY LTD,
5. WRIGHT PROSPECTING PTY LTD AND
6. L.S.P. PTY LTD

Respondents
(Appellants)
(Defendants)

RECORD OF PROCEEDINGS

PART II
VOLUME II

Ince & Co.
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(RESPONDENT) (PLAINTIFF)

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SOLICITORS FOR THE RESPONDENTS
(APPELLANTS) (DEFENDANTS)