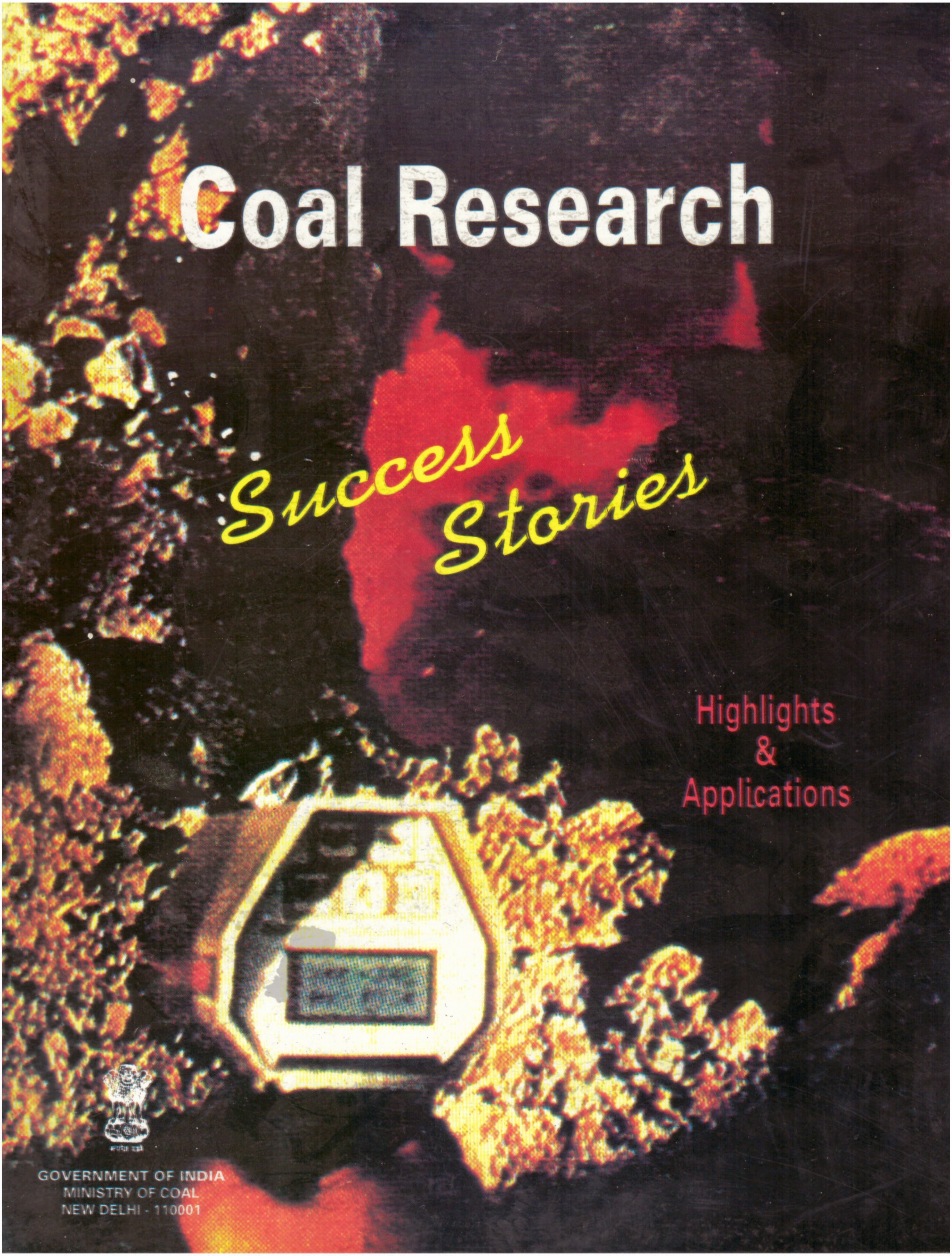
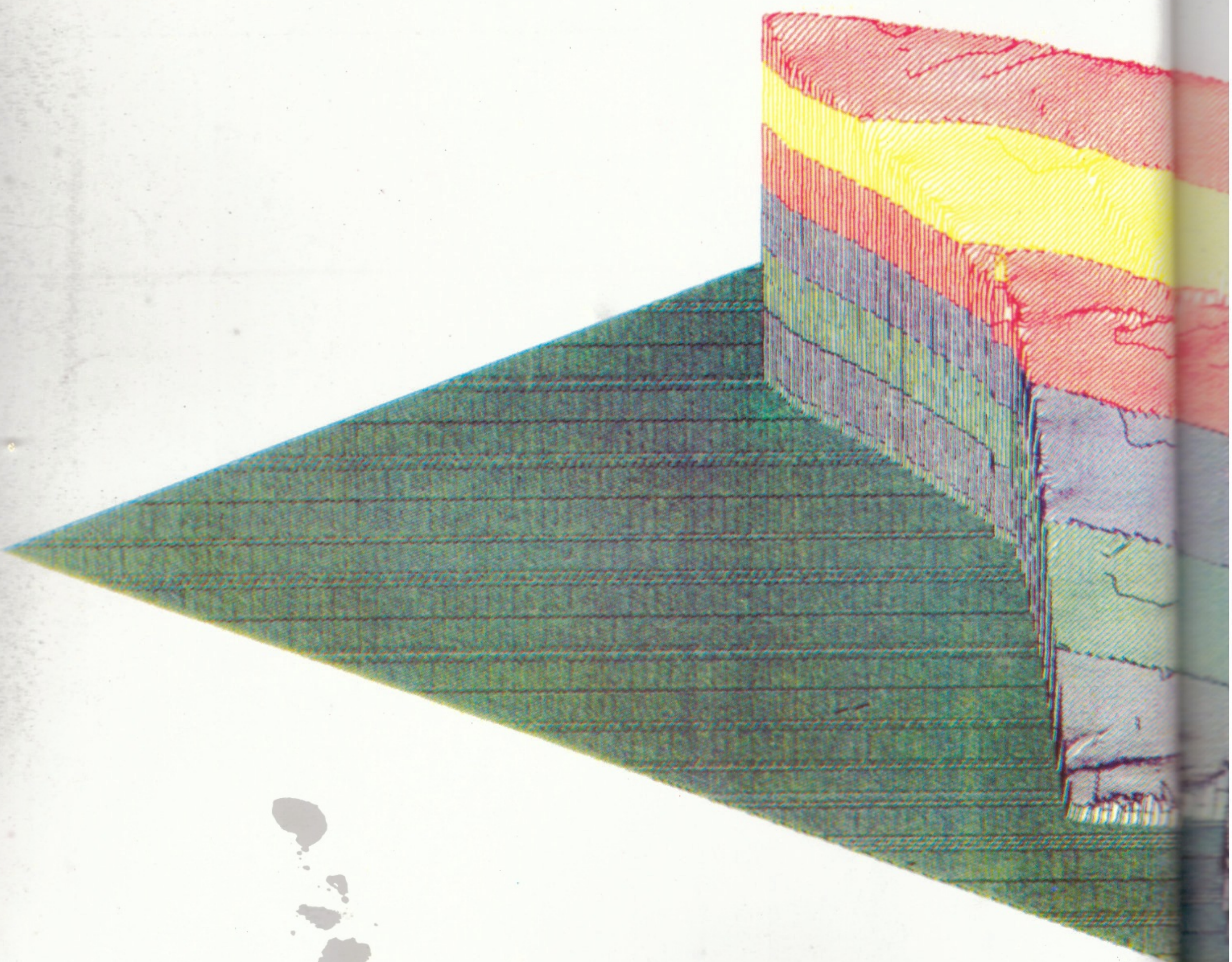


Coal Research

Success Stories

Highlights & Applications

GOVERNMENT OF INDIA
MINISTRY OF COAL
NEW DELHI - 110001



MINISTER OF STATE FOR COAL
(INDEPENDENT CHARGE)
INDIA
NEW DELHI

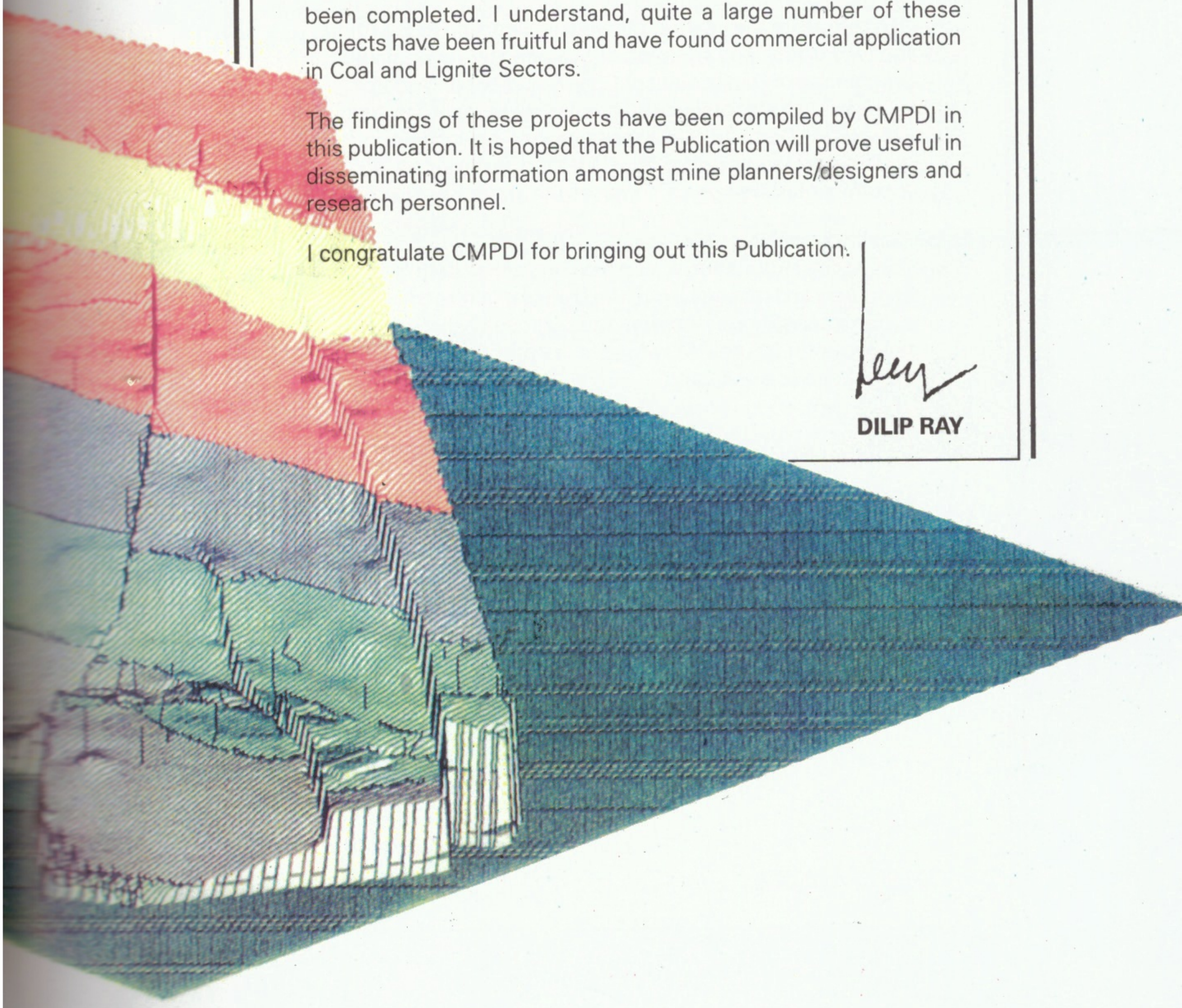
MESSAGE

Since the launching of "Coal Science & Technology Plan" by the Government of India in the year 1975, I believe, 158 Coal S & T projects in the thrust areas of Mining & Exploration, Coal Beneficiation, Coal Utilisation and Environment & Ecology have been completed. I understand, quite a large number of these projects have been fruitful and have found commercial application in Coal and Lignite Sectors.

The findings of these projects have been compiled by CMPDI in this publication. It is hoped that the Publication will prove useful in disseminating information amongst mine planners/designers and research personnel.

I congratulate CMPDI for bringing out this Publication.

DILIP RAY



GOVERNMENT OF INDIA
MINISTRY OF COAL
NEW DELHI

MESSAGE

Research and Development plays a vital role in creating a sound technological base for the different sectors of the economy.

R&D efforts in the coal sector were initiated in 1976 with the formulation and adoption of Science and Technology programme of Department of Coal. A number of research projects in the identified thrust areas were taken up and completed. Some of these research projects have found application in the industry. CMPDI's attempt to put together the findings of some of the more successful R&D projects in the form of a publication is laudable.

This handy information would be of immense help to the engineers and researchers in the field of mining and allied subjects, and I hope will serve the purpose of sharpening the focus for future R&D projects in order to benefit the indigenous coal industry.

S. NARAYAN
Secretary

COAL INDIA LIMITED
(A Govt of India Enterprise)
10, NETAJI SUBHAS ROAD
CALCUTTA

MESSAGE

The history of Coal Mining in India dates back to more than two centuries, but the purposeful indigenous research efforts were initiated only after independence with the establishment of the Council of Scientific and Industrial Research (CSIR) laboratories, as also through leading Coal Mining Companies. Organised and co-ordinated research activities in the Coal Sector, however, could be undertaken only after nationalisation and the subsequent formulation of the "Coal Science and Technology Plan" by the Government in 1975. The Coal research programme is presently administered through an Apex Scientific Body i.e. Standing Scientific Research Committee (SSRC). Central Mine Planning & Design Institute (CMPDI), a subsidiary of Coal India Ltd. has been identified as the Nodal Agency to co-ordinate the research activities in Coal & Lignite Sectors.

Quite a large number i.e., 158 S&T Projects have been completed since inception of Science & Technology programme in Coal and Lignite sectors. These have brought out significant results for the benefits of the coal industry.

In order to disseminate the research results of successful S&T Projects amongst the mining community and to seek wider application of research findings, CMPDI has been, for the last few years, bringing out various publications with several visual presentations which have been well received by the users. However, this illustrated booklet briefly gives industrial applications and benefits derived from some of the prominent research projects.

It is hoped that this publication will serve the purpose of disseminating information of these successful research projects, and further the cause of wider application of the findings for the benefit of society at large, and for the Coal & Lignite Sectors, in particular.

P. K. SENGUPTA
Chairman

GOVERNMENT OF INDIA
MINISTRY OF COAL
Shastri Bhawan
NEW DELHI

MESSAGE

The real thrust and co–ordinated R&D Programme in coal sector were initiated only in the year 1975 after constitution of Standing Committee on Science & Technology (SCOST) in the Department of Coal. A 15 year Science & Technology Plan was initiated with Central Mine Planning & Design Institute Ltd., (CMPDI) of Coal India Ltd. (CIL) as a Nodal Agency to co–ordinate the R&D activities funded under this plan. CMPDI, apart from its primary activities of exploration, project planning and designing, has been co–ordinating and initiating a number of S&T Schemes to provide practical application to laboratoy findings, and to conduct field trials of various suitable mining technologies. The other agencies carying out R&D work under this programme, have been CMRI, CFRI, NIRM, Regional Research Laboratories, Educational Institutions like ISM, BHU, IIT, Kharagpur, IISC, Bangalore, etc. in addition to the coal producing companies.

The R&D set up was subsequently revamped in the year 1984 by the Government of India and an Apex Scientific Body i.e., Standing Scientific Research Committee (SSRC) was constituted under the Chairmanship of Secretary (Coal) to plan, programme, budget and oversee the implementation of the R&D projects in Coal and Lignite sectors, and to seek application of the research findings.

The SSRC, in turn, is assisted by 4 Sub–committees, each dealing with one of the following four major areas of Coal Research :

Production, Productivity & Safety

Goal : To meet the quantitative and qualitative production targetswith due emphasis on Productivity, Conservation and Safety.

Coal Beneficiation

Goal : Updation of quality parameters through optimised beneficiation techniques.

Coal Utilisation

Goal : (a) Development of techniques and technology for efficient utilisation of available coal resources

(b) Substitution of Oil by Coal

Environment & Ecology

Goal : (a) Integration of coal mining development activities with ecological conservation

(b) Minimise air pollution, water pollution, land degradation and other environmental hazards and to take steps for restoring such resources to original or better use.

The above identified thrust areas were given wide publicity through a booklet "Guidelines for implementing Coal Research Projects", circulated amongst various concerned organisation/institutions.

In order to disseminate the outcome of the research of successful S&T Projects amongst the mining community and to seek wider application of research findings,CMPDI has been, bringing out various publications with several visual presentations which have been well received by the users. This illustrated booklet briefly presents industrial applications and benefits derived from some of successful research projects.

It is hoped that this booklet will serve its purpose and further the cause of wider application of these scientific findings.

N.N. GAUTAM
Advisor (Projects)

FOREWORD

R&D activities in Coal Sector are administered under the overall guidance of Standing Scientific Research Committee (SSRC), attached to the Ministry of Coal, Govt. of India. Central Mine Planning & Design Institute (CMPDI), a subsidiary of Coal India Limited, has been nominated as a Nodal Agency to co–ordinate the R&D Programme.

The SSRC in turn is assisted by 4 Standing Sub–committees, each dealing with one of the following four major areas of Coal Research :

* *Production, Productivity & Safety*
* *Coal Beneficiation*
* *Coal Utilisation*
* *Environment & Ecology*

The prime objective under R&D Programme of Coal Sector is technology assessment/development and its transfer to industry for gainful application. Considerable effort has been made for the industrial exploitation of the R&D efforts.

Since inception of this programme, 158 S&T Projects have been completed till end of VIII th Plan period. Some have met with limited success and a few even with negative findings of failures. However, quite a large number of these S&T projects have resulted in tangible benefits in the Coal Industry. While findings of the various research projects have been reported in greater details with systematic indexing in a separate volume titled " Assessment of benefits from completed S&T Projects " most of the more prominent S&T Projects under this research programme in Coal & Lignite Sectors are briefly presented in this illustrated booklet.

It is hoped that this booklet would be useful to all the Research Personnel, Mine Planners, Designers and Practising Engineers involved in the process of Coal Exploration, Mining, Beneficiation, Utilisation and allied fields.

S. K. VARMA
Chairman – cum – Managing Director
CMPDIL

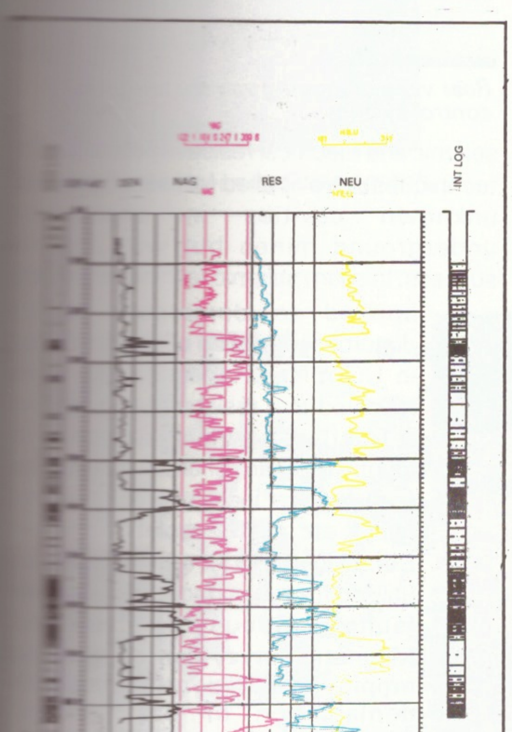
CONTENTS

GEOPHYSICAL EXPLORATION

The nationalisation of Coal Industry and the Oil crunch in early 70's dictated a quantum jump in coal production. This necessitated opening of larger capacity mechanised mines, both opencast and underground and called for a far more accurate exploration model of the coal reserve since indicted features like fault, dyke or unforeseen water seepage etc. could stall mining and cause huge loss of money. Efforts were made through sustained and continuing R&D activity at Central Mine Planning & Design Institute to increase the pace of detailed exploration and make it cost effective with multi parametric, multi disciplinary data for a better geological modelling of the coal resources. Many such R&D programmes have been used gainfully, and are being employed on routine basis for geological exploration.

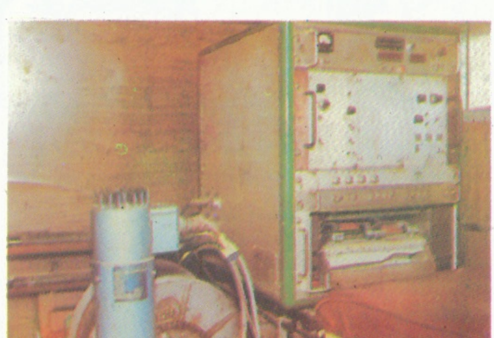
Geophysical Logging of Boreholes

The conventional practice of 100% core drilling of boreholes for exploration has gradually been reduced, and faster and cost effective non coring drilling aided by multi parametric geophysical logging is being introduced. In Mchuchuma Coalfield, Tanzania nearly 50% drilling was carried out by non coring method. A suite of geophysical logs consisting of SP, resistance, focused resistivity, natural gamma, density, neutron, sonic, caliper etc are recorded. Interpretation is done mostly through in-house developed SASLINT software, or sometimes manually, to provide data on lithology and coal quality. The generated data compares closely with that obtained from core analysis data. Geophysical logging is also a convenient tool to account for core loss in coring boreholes and also for generation of hydrogeological data especially for identification and delineation of aquifers and aquifer properties.



Saslint Interpretation for Lithology

The system of geophysical logging has now been integrated into the routine exploration programmes of the coal sector, and a number of mobile geophysical loggers have been procured and commissioned providing valuable input data for mine planning and designing. CMPDI alone has procured nine sophisticated loggers, and about 50,000 depth metres are being logged every year, thus providing very useful input to mine planning. Based on this successful


Front View of Logger, Winch and motor

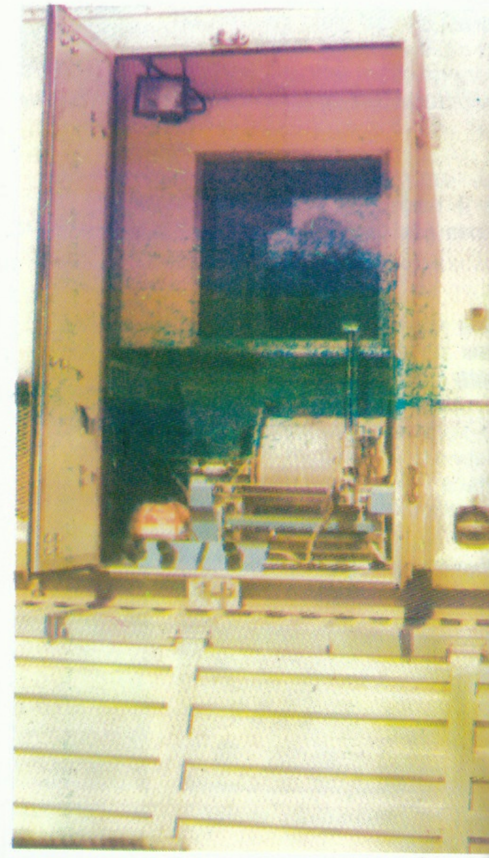
application, CCL has also procured logger which is being used routinely to generate lithological information for their use.

Table -1 gives the geophysical logging done by CMPDI during 1994-95, 1995-96, 1996-97 & 1997-98.

Table 1 *(Depth in meters)*

Area	1994-95	1995-96	1996-97	1997-98
RI-1	9231	8967	9162	7025
RI-2	7166	7725	11825	194
RI-3	10368	701	6190	8606
RI-4	1300	4191	5046	5047
RI-5	5164	160	958	4668
RI-6	1448	—	—	3018
RI-7	5030	5825	2980	—
HQ	—	7072*	—	—
Total	**39709**	**34641**	**36162**	**28558**

** Geophysical logging for NDC Tanzania Project*



Rear view of logging van showing winch control system

Geophysical Exploration Strategy

Research and investigations carried out under this programme have defined the geophysical strategy for depicting sub-surface structure, strata sequence, coal seam incrop, basic dyke intrusion etc. More recently micro gravity, seismic and Electrical resistivity tomography techniques were applied for identification of unknown cavities in abandoned underground mines but with limited success. In seam seismic technique is being applied to demarcate faults/ disturbances ahead of working faces in UG mines. Investigations have revealed that resistivity and seismic refraction surveys can help in identifying many shallow sub-surface features like incrop of coal seams, faults, etc. High Resolution shallow Seismic (HRSS) survey can be utilised for sub surface structures like faults, continuity of strata etc. Magnetic survey can be gainfully employed for identification and demarcation of basic dykes. Subsequent to routnisation of above

Worden Gravimeter

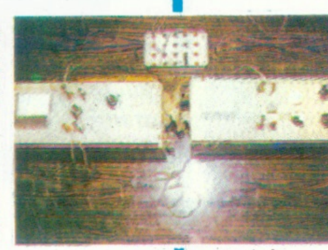
Fluxgate Magnetometer

surveys for coal exploration, integrated geophysical surveys consisting of Electrical Resistivity Profiling and Vertical Electrical Sounding (VES). Gravity and Magnetic surveys were conducted with high degree of success in locating Manganese and Iron Ore. Other applications include application of Electrical resistivity surveys for location of borewell/tubewell sites with very high degree of success.

Electrical Resistivity and Seismic Refraction Surveys

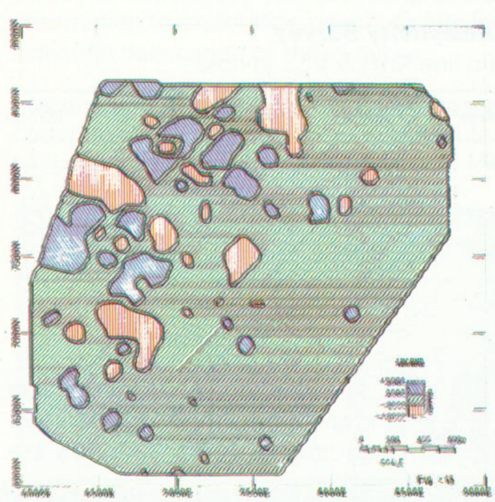
Extensive field investigations followed by detailed scientific analysis of data so generated have revealed that these surveys could be gainfully used for sub-surface geological mapping including location of coal seam incrops, location of shallow faults, overburden studies including evaluation of the rippability characteristics of overburden and location of water bearing horizons etc,

D. C. Resistivity meter

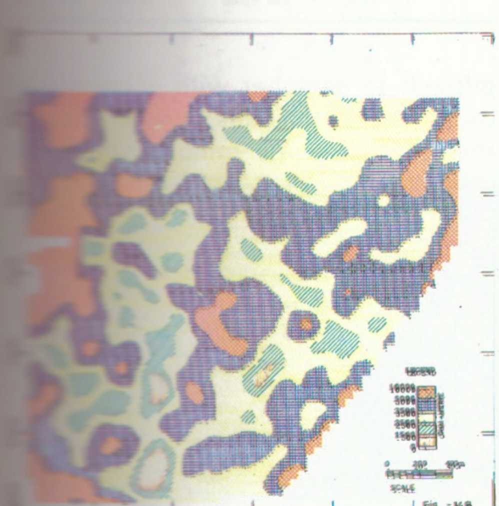


Low frequency resistivity meter (in testing mode)

[illegible] channel Engineering Seismograph

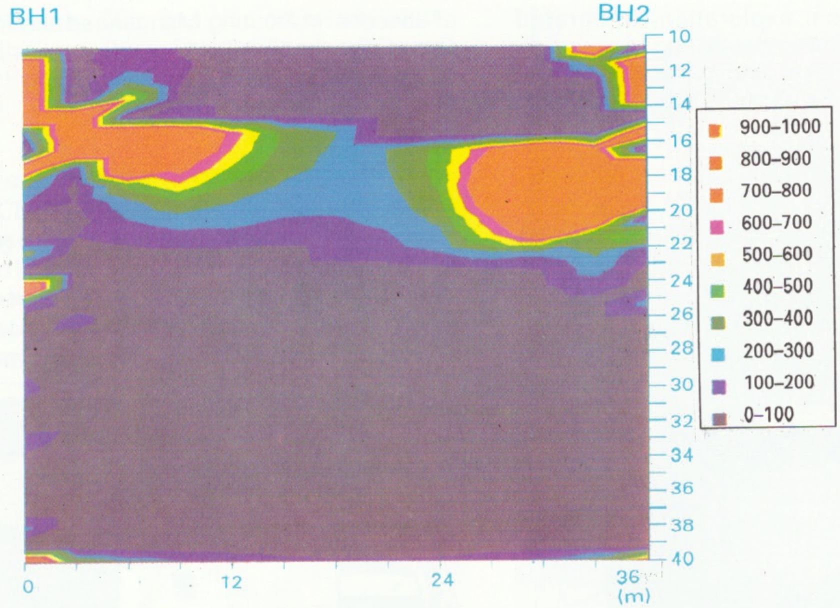


Residual Magnetic Anomaly map



Resistivity distribution from profile data

where the mineable area is covered by detrital mantle and soil. These techniques are now being routinely used for boundary faults, coal incrops and overburden studies. Nearly 100 line kilometre survey is being carried out every year to generate the above information. Work done on Resistivity Survey by CMPDI during 1994-95, 1995-96, 1996-97 & 1997-98 are given in Table -2.



Crosshole. Resistivity Tomography Resistivity Range : 200 to 300–Goaf & >600 – Coal

Table 2

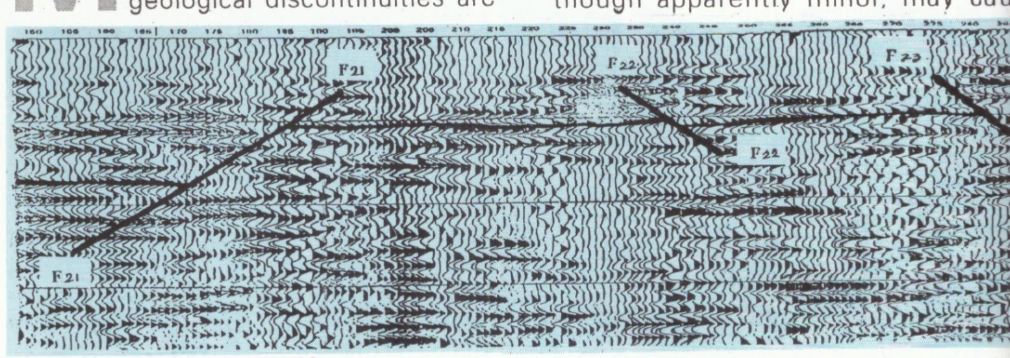
Resistivity Survey
(In line Kms & VES in nos)

Area	1994-95	1995-96	1996-97	1997-98
RI-1	8.0 (2 VES)	—	5.4 (9 VES)	9.4 (3 VES)
RI-2	21.0	11.3	5.6	25
RI-3	10.32 (4 VES)(	15.2 16 VES)	11.48 (12 VES)	12.9 (10 VES)
RI-4	11.45 (35 VES)	10.3 (16 VES)	25 VES	34 VES

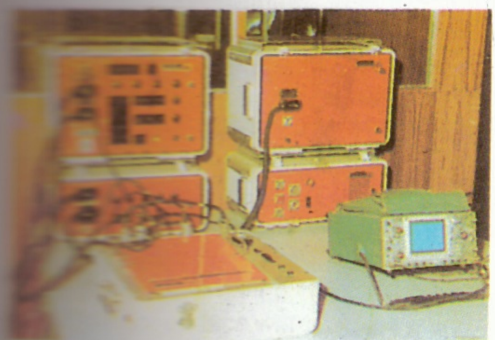
Area	1994-95	1995-96	1996-97	1997-
RI-5	20.6 (16 VES)	17.2 (23 VES)	26.2 (28 VES)	35.8 (4 VE
RI-7	0.23 (3 VES)	20 VES	11	6. (4 VE
HQ	17.21 (16 VES)	4.85 (1 VES)	107.5 (136 VES)	-
Total	**88.81 (76 VES)**	**58.85 (55 VES)**	**167.18 (210)**	**89.1 55 (VE**

High Resolution Shallow Seismic (HRSS) Survey

Minor geological features like strata swings, faults and other geological discontinuities are difficult to decipher with convention exploration techniques. These feature though apparently minor, may caus



Seismic section obtained by HRSS survey appreciable hindrance in operation of mechanised and capital intensive mines thereby causing substantial loss of revenue and under-utilisation of machinery. To overcome this problem, the technique of High Resolution Shallow Seismic (HRSS) survey was conceived. Data acquisition system alongwith accessories were imported and with indigenous application technology — both in terms of data acquisition, processing and interpretation of field data were evolved and perfected.



Digital Seismic Equipment for HRSS Survey

The continuous profile data, unlike point data provided by bore hole drilling, not only helps in detection of minor faults and other geological discontinuities in between boreholes alongwith complete sub-surface features along these profile lines.

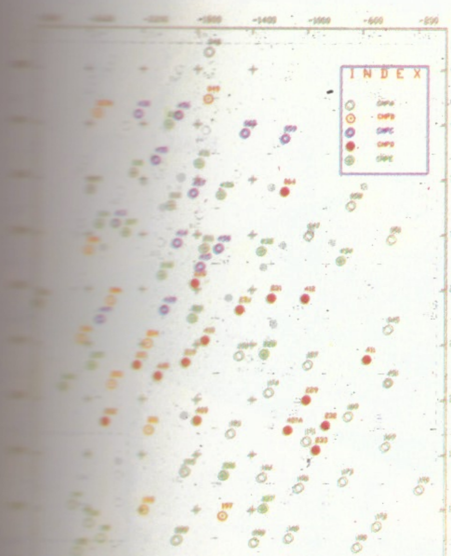
The HRSS technique utilising digital seismic instruments, has been integrated into routine exploration programme of coal sector, and has been found to provide very useful information for detailed mine planning and designing. Nearly 40 line kilometre survey is being done every year by CMPDI, thus providing quite a useful input to coal sector.

Magnetic Survey

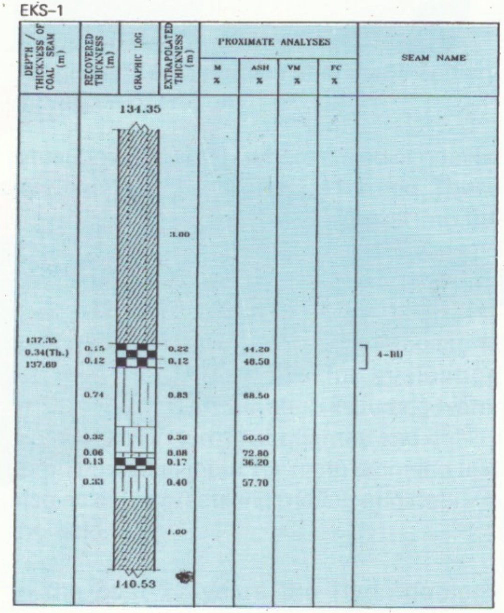
The methodology for location of basic intrusive dykes has been successfully evolved and established using magnetic survey technique. The extent of the dykes can very well be demarcated even if the dykes are buried under soil cover. Nearly 40 line kilometre survey is done every year providing useful information to exploration geophysicists for scientific delineation of these dykes.

Computer Applications in Coal Exploration

Development of computer applications in various branches of coal exploration continued. In the process, in-house development of PC based software packages is taken up. A computer package CEMPGEODOC is developed in–

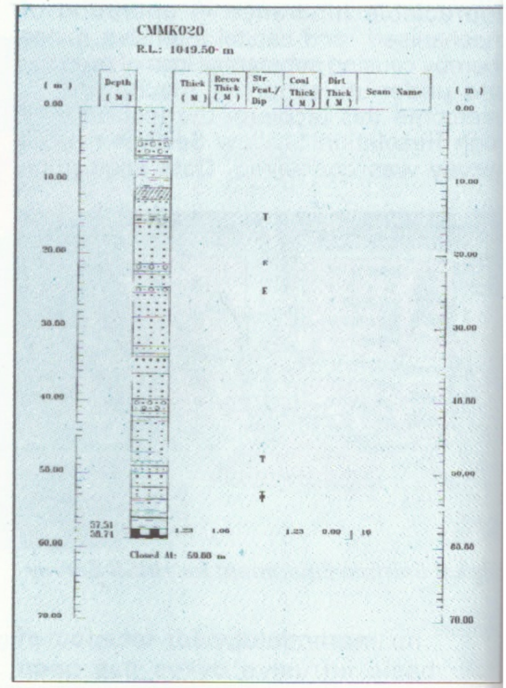


PC Based CEMPGEODOC Borehole location Plan



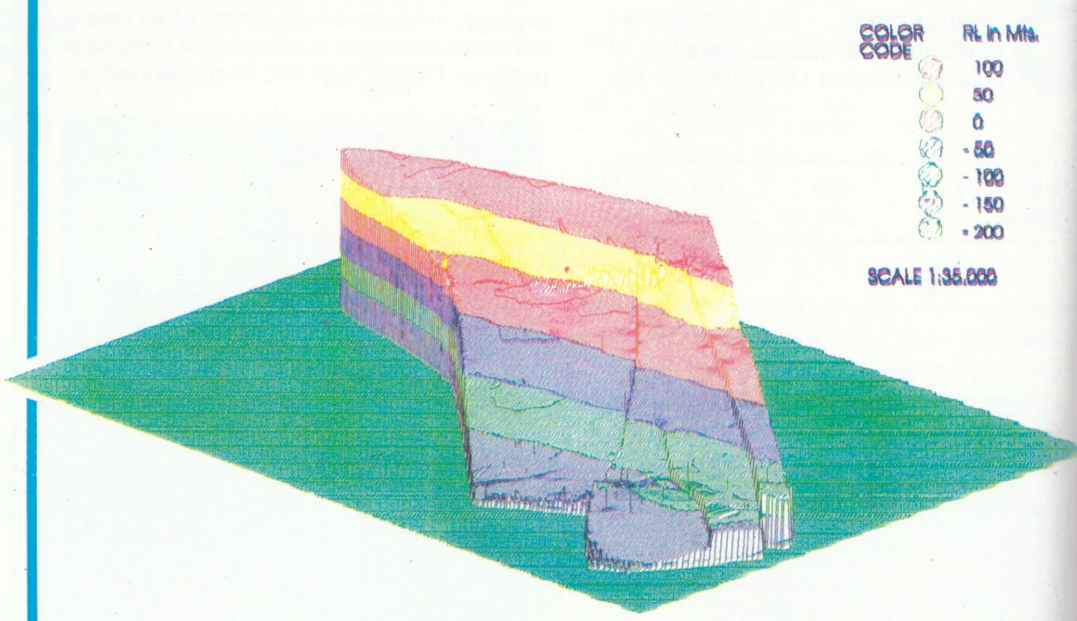
PC Based CEMPGEODOC Graphic Borehole Seam-structure house on PC platform as a front end to the MINEX on VAX and the PC software is routinised in the Regional Institutes. This package after validating the basic lithology and analytical data outputs, the graphic lithologs, short logs, seam correlation aids, seam structure, bore hole location plans and graphic correlation chart, on PC based plotters.

The in-house developed SASLINT package on VAX computer for interpretation of geophysical log data is being ported to PC's for routinisation of geophysical log data processing (ref. photograph : SASLINT Interpretation for Lithology) at the Regional Institutes.



PC Based CEMPGEODOC – Graphic Borehole Litho log

Geological structure ▼



HYDROGEOLOGY

Water plays a dominant role in mining/reclamation, both in terms of quantity and quality. The water also defines the mining/reclamation methods to be adopted and the equipment to be used. Wet mining conditions influence in less productive mining, less efficient equipment and more expensive explosive. With proper management of water system in mining, water can be considered as a by-product of mining rather than a mine waste. Thus making mining more sustainable.

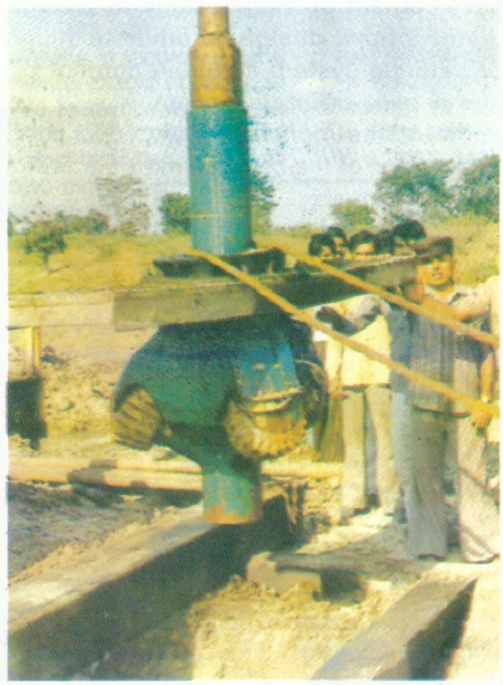
Water met in mine-field is a part of the hydrogeologic cycle. The water may be passing into the mining field directly as rainfall or from surface water bodies or from the subsurface water bearing rocks i.e. groundwater. Two types of problems faced under different mining conditions :

— Make of water in mining due to surface water which is controlled by drainage and rainfall runoff relationship,

Large dia casing being lowered at Mahabir colliery

— Occurrence of water in underground and opencast excavations, which depends largely on the geological control associated with conditions created by mine.

The above mine water inrushes, under certain mining activities, create hazardous



36" dia hole being drilled at Mahabir colliery for rescue operation

situations, especially where caved or goaved (underground void) areas are formed. These inrushes may be sudden or gradual into the mine workings, endangering safety and production process. R&D activities in this direction were, therefore, initiated in 1976, with a small nucleus of hydrogeologists to develop methodologies for evaluating hydrogeological parameters including water inflow, both in terms of quantity and quality as an essential input for mine planning and also an aid to practising mining engineers in the field.

In the past 22 years the Hydrogeology department of CMPDI has developed technologies, relating to Water

Management in coal Mining Environment. It has also developed a consciousness in the industry, the water management is an important acitivity and proper water handling can not only lead to effective mining in very difficult environment, but at the same time, could reduce cost of coal production. The investigations carried out have led to development of methodology to predict water inflow, design of advance mine dewatering system and development of overall mine drainage concept. Some of the more important applications of the concept and development are :

— Mining with caving under high water bearing strate in Wardha Valley and Jamuna-Kotma coalfields, obviating the costly sand stowing operations.

— Design and application of advance mine dewatering system for Rajmahal, ECL and Padmapur, WCL opencast projects resulting in much reduced groundwater inflow even during monsoon.

— Futuristic, modelling for both resource quantification and solute transportation is being carried out.

— As a corollary, expertise for drilling large diameter application at the time of rescue operations at Mahabir Colliery, Raniganj coalfield and production support.

Well Testing at UCG Project site, Rajasthan

Well construction at Mchuchuma Project, Tanzania

It is a matter of pride that the CMPDI Hydrogeology group has nationally and internationally trained manpower to work on the various aspects of Water Management including socio-economic impacts. The expertise developed is being routinely used to predict hydrogeological status and design dewatering system for various exploration and mining blocks. the group has also been excelling in providing the total water management consultancy to Coal India, and to outside organisations also.

Hydro–geological investigations undertaken by CMPDI during the last 3 years are given in Table – 3.

Table 3

Hydro-geological jobs undertaken during 1994-95, 1995-96 & 1996-97

Sl. No.	Items	Company	Status	Remarks
I	(A) UNDP PROJECT			
	Modelling and control of water systems in Coal Mining Environment			
	(i) Chandrapur Area, Wardha Valley	WCL	Report under preparation	UNDP funded
	(ii) Rajmahal Area, Hura Coalfield	ECL		UNDP funded
	(B) S&T PROJECT			
	Hydrogeological investigations for Underground Coal Gasification of Lignite deposits of Merta Road Rajasthan	MOC SSRC	Completed 1994-95	
II	HYDROGEOLOGICAL INVESTIGATIONS			
	(i) Sonpur Bazari	ECL	Completed 1994-95	
	(ii) Ghusick	ECL	— do —	
	(iii) Dakhinkhanda	ECL	— do —	
	(iv) Barmondia	ECL	— do —	
	(v) Kharkharee-Dhamabandh	BCCL	1996-97	
	(vi) Moonidih	BCCL	1995-96	
	(vii) Parbatpur	BCCL	—	Further work stopped due to change in exploration programme
	(viii) Bhatadi	WCL	1995-96	
	(ix) Padmapur CHP	WCL	1995-96	
	(x) Padmapur Advance Dewatering	WCL	1995-96	
	(xi) Ballarpur	WCL	1995-96	
	(xii) Wirur Chincholi	WCL	1995-96	
	(xiii) Chincholi Underground	WCL	1995-96	
	(xiv) Indian Rare Earths Ltd., OSCOM, Chhatrapur, Orissa	IREL	1995-96	
	(xv) Mchuchuma Coalfield, Tanzania	NDC Tanzania	1995-96	
	(xvi) Baranj, Bander, Lohara Blocks, Wardha Velley Coalfield	CICCO	1996-97	

Sl. No.	Items	Company	Status	Remarks
(xvii)	Sasti Colliery	WCL	1994-95	
(xviii)	Morpar Area (Majiri Incline)	WCL	1994-95	
(xix)	Karmatand and Alakdiha	BCCL	1996-97	
(xx)	Water balance studies for Basundhar block Ib Valley	MCL	1996-97	
(xxi)	Tawa Underground Mine	WCL	1996-97	
(xxii)	Kumda and Balrampur	SECL	1996-97	In progress
(xxiii)	Bhilai Steel Plant		due to delay in providing drilling support by BSP	Work suspended
(xxiv)	Jhingurdah	NCL	1995-96	
3.	WATER SUPPLY INVESTIGATIONS			
(i)	Water Supply Investigation in Latur, Earth quake hit area	WCL	1994-95	
(ii)	Madhuband	BCCL	1995-96	
(iii)	Muraidih	BCCL	1995-96	
(iv)	Captive Power Plant, Kedla Washery Area	CCL	1996-97	
(v)	Jharkhand Deshaling Plant	CCL	1996-97	
(vi)	Deshaling Plant, Kedla CHP Area	CCL	1996-97	
(vii)	Bansara Colliery (Kanustoria Area)	ECL	1996-97	
(viii)	Jambad	ECL	1996-97	
4.	PRODUCTION SUPPORT			
(i)	Advance Dewatering at Rajmahal OCP	ECL	1994-95	
(ii)	Large Dia drilling BCCL area	BCCL	1995–contd.	
(iii)	Large Dia drilling in Ballarpur area	WCL	1995-96	
(iv)	Advance dewatering at Padmapur OCP	WCL	1994-95	
(v)	Advance dewatering at Kakri	NCL	1994-95	
(vi)	Large dia drilling at Belabad Colliery	ECL	1995-96	

MINING METHODS

The drastically changed coal scenario of the post-nationalisation period, achieving a production jump from 72 Mt in 1973 to 285.6 Mt (All India) in 1996-97 and is expected to increase to 345.8 Mt by 2001-02, called for a rapid but judicious mechanisation of exploitation techniques. The prevalent method of Bord and Pillar mining accounting for the major output of underground coal is characterised by low production and productivity in addition to blocking of large reserves in thick, steep and contiguous seams. The method is also unsuitable for working deeper horizons. Research efforts were initiated to overcome the existing limitations, by introducing the following innovations.

Side Dump Loader (SDL)

Mechanised Bord and Pillar Mining

Since the Bord and Pillar system has already been in vogue, it was considered prudent to improve the system performance by appropriate mechanisation. Investigations revealed that manual coal loading operation apart from causing human drudgery, is the weakest link in the production chain for achieving optimum results. Consequently, mechanised coal loading and face transport with Side Discharge Loaders (SDLs) and Load Haul Dumpers (LHDs) was introduced to enhance the efficiency of the system. This, inter-alia includes better roof control and improved safety and a more efficient coal revacuation. Further, as a result of large scale R&D investigations undertaken in various mines about physico-mechanical properties of the strata, in-situ strata control observations, design and development of appropriate support system, it was possible to introduce mechanised depillaring operations in a number of mines using SDLs and LHDs in addition to their use in mechanised development workings. Nearly 151 mines are already using such mechanised face loading and inbye transport system. 745 SDLs and 49 LHDs are already in operation contributing to a production of about 18.31 Mty in mines of Coal India Limited (CIL). A production level of 26 Mty by mechanised loading has been projected by the terminal year of the IX Plan. The thrust on this intermediate technology is being continued in u.g. mines of CIL. Performance of SDL/LHD faces in CIL mines for the last 3 years is given in Table -4.

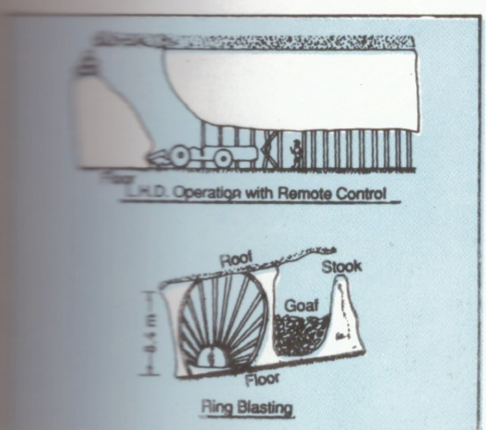
Table 4

Parameter	1994-95	1995-96	1996-97
1. Population of SDLs & LHDs in CIL mines	595	760	794
2. Production from above mechanised mines, Mt	13.6	15.98	18.31
3. M/c Productivity on roll basis, tonnes	70	77	81
4. Total production from CIL U/G mines, Mt	55.61	54.82	55.18
5. No. of mines covered by mechanisation	135	141	151
6. Total no. of U/G mines	355	350	357

Load Haul Dumper (LHD)

Blasting Gallery Method

Extraction of coal from thick seams, developed on Bord & Pillar system, has been deplorably low to the level of only 30%, even under the most favourable conditions. The small private holdings, cheap labour, selective mining for the market demand and desire for quick return on investment did not call for any innovation in the methods in vogue in pre-nationalisation period. Conservation of dwindling resources, utterly neglected till then, assumed significant importance, and problems of thick seam mining got serious attention of the nationalised coal sector.

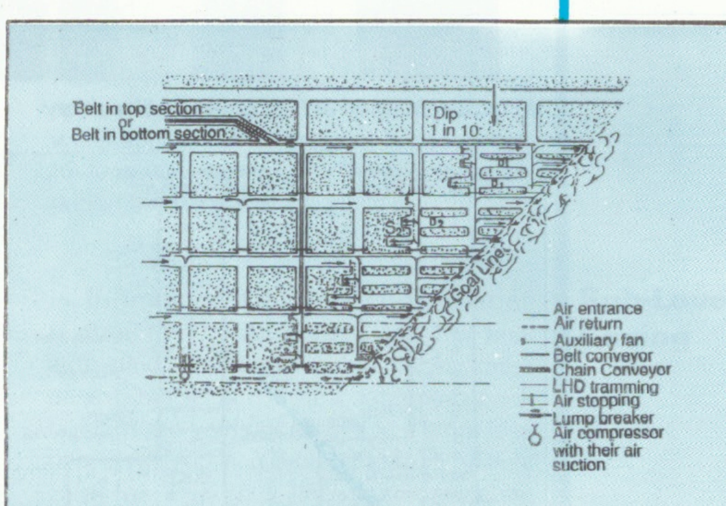


Pillar extraction by Blasting Gallery Method

Since large reserves of good quality coal were locked up in developed Bord and Pillar workings (over 2500 Mt), scientific investigations were initiated for safer and faster liquidation of this coal with a maximum possible recovery percentage. Eventually, research investigations led to the introduction of blasting gallery method, based on a method developed in France, where the full seam thickness is blasted in one operation, and the blasted coal is removed by remote controlled LHDs. The LHDs with remote control obviate the necessity of presence of miners in the blasted area, either for coal loading or supporting, and thus permit safe extraction of greater seam thickness in a single operation.

Gallery Blasting method was introduced under the R&D Project in technical collaboration with CdF, France in 7.5 m thick X seam of East Katras Colliery, BCCL. Three panels H, J & E have been successfully worked in this mine. The first trial of this new method of work was at East Katras followed by Chora, ECL in 7.5 m thick seam. Coal recovery was found to be about 70% which was much higher than that obtained through conventional methods. The panel OMS achieved was about 2 tonnes. Direct saving in cost of production due to elimination of sand stowing was about Rs. 120/te to Rs. 150/te. The success achieved at the trial stage has led to projection of this system of mining in several other mines. Now it has been planned to introduce this method at Parasea, and New Kenda mines of ECL. Further, this technology is under consideration for seam - III at Chirimiri colliery, SECL.

The system has already been replicated at GDK-10, GDK-8 Collieries of SCCL with good performance. It could achieve a production level of 900 tpd on sustained basis with an OMS of over 5 te and percentage recovery as high as 85%.

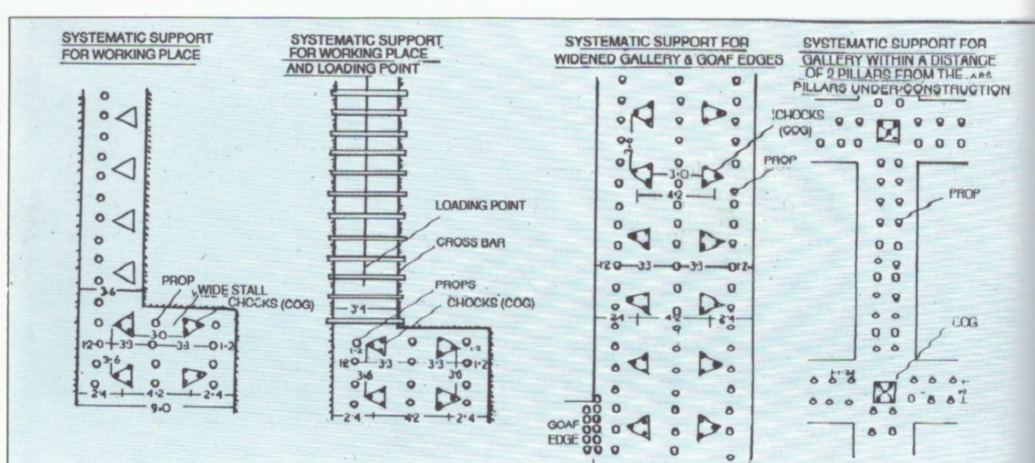


Depillaring layout and LHD tramming in Blasting Gallery Method

Wide Stall Method

Of the 2500 Mt of coal locked up in pillars, a substantial portion is sterilised due to presence of surface structures viz. townships, waterways, roads, etc. above the coal seams. Only partial extraction from these areas is possible in view of the need to avoid damage to surface structures. The prevalent method under such situations is splitting of coal pillar followed by stowing of openings. The method, however, has a drawback that percentage recovery falls down sharply with increasing seam thickness due to adverse slenderness ratio whereby, in a seam of 16m thickness, percentage recovery may be as low as 30 to 35%. With a view to overcome this limitation, "Wide Stall" method of mining was conceived, and laboratory tested with Equivalent Material Modelling technique and finally successfully field experimented at East Bhuggatdih Colliery of BCCL in a 16.5 m thick seam lying below built up areas. The method involved formation of 7–9 m Wide Stall to full working height leaving pillar core as a natural support.

Wide Stall Method at East Bhuggatdih colliery



Support Plan of wide stall method

Technical comparision of % of extraction and safety factor with (a) Conventional Bord & Pillar System, and (b) Wide Stall method of working is given in Table 5.

Table-5

	Gallery Size (m)				
	3.6	4.0	4.5	5.0	5.5
Conventional stooking and splitting method					
Development in two sections of 2.4m height					
Recovery, %	6.5	7.2	8.1	8.9	9.6
Safety Factor	4.6	4.5	4.4	4.3	4.2
Final extraction in two sections of 7.2m + 6.4m and pillar 15 x 15m size 3m parting					
Recovery, %	34.6	37.8	41.7	45.5	49.1
Safety Factor	1.05	0.98	0.90	0.82	0.75
Wide stall method with 2 sections of 7.2m + 6.4m and 3 m parting					
Gallery size, m	6	7	8	9	10
Solid pillar, m	24	23	22	21	20
Recovery, %	29.5	33.7	37.8	41.7	45.5
Safety Factor	1.56	1.44	1.32	1.21	1.11

The R & D effort showed that over 45% overall recovery with a safety factor more than one was possible. Scientific investigations revealed that pillars left in situ were not significantly stressed and there was hardly any surface subsidence.

Scientific investigations revealed that pillars left in-situ were not significantly stressed and there was hardly any surface subsidence. The full seam thickness was extracted in four slices separated by 3m thick coal band in the middle. The first and the third slices (numbered in ascending order) were already developed, while the second and the fourth slices were virgin.

The method essentially consists of widening of the existing 3m galleries to 9 m and systematically supporting the widened galleries (also called stalls), without disturbing the core of the pillar and finally stowing the stalls, so created.

Based on the successful field experiments, the method has already found repeat applications in a couple of mines, and a much wider application is foreseen in near future to recover good quality coking coal left underneath important surface structure.

Sub-Level Caving

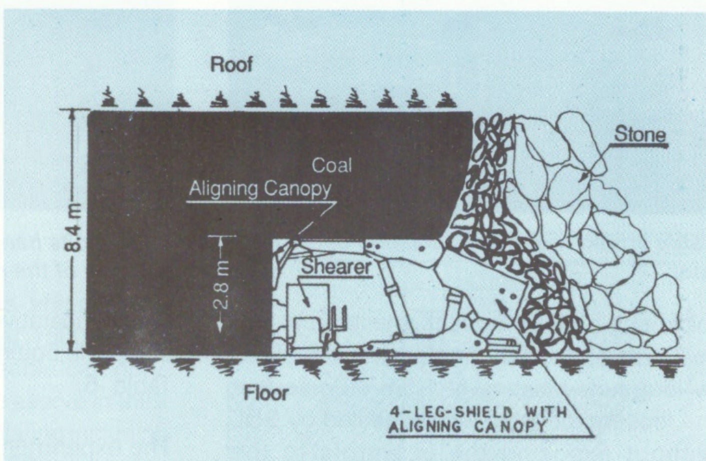
Concurrent to the development of an exploitation method for the developed coal seams by Bord & Pillar, a close attention was directed towards development of an optimum extraction system of the virgin thick seams, which comprise about 70% of the total coal reserve in India.The prevailing method of Bord & Pillar mining can extract only about 6% to 10% from the first development workings in formation of pillarrs and galleries (sometimes called bords), and the final extraction (depillaring) either necessitates an expensive and time consuming back filling of the voids or results in a large loss of coal when caving is resorted to in the final workings. Coal thus lost is irrecoverable. Research investigation undertaken in this regard to conserve the coal in Indian conditions has led to examination of

Sub-level caving application with the exception that the coal needs to be softer in the application of total underwinning. As the name implies the bottom section of the coal seam, having more than 6m thickness, is developed and extracted by longwall method with caving. The complete top section seam is allowed to cave on the powered supports. The broken coal is withdrawn through the window provided on the top of the canopy. Other situations in the longwall face are similar to sub-level caving except that only one set of powered support equipment is required in a total underwinning face and development is also much less, resulting in cheaper mining of coal.

The first sub-level caving face was opened at East Katras Colliery of BCCL and results are quite encouraging. It has been possible to achieve about 850 tpd in a 7.5 m thick seam with recovery over 60%.

Based on the successful operation of the technology at East Katras, the system can now be introduced in suitable geo-mining conditions of various coalfields in India.

Longwall Sub-level caving — Soutirage



Mining of Thick Seams Standing on Pillars with Cable Bolt Support

Thick coal seams accounted for nearly 60% of the total coal reserve of India. The seams under shallow cover were developed on pillar in single or multiple sections and depillaring was often fraught with danger of spontaneous heating because of low recovery. The level of recovery from seams around 5 to 8m thickness has been below 40% inspite of all possible efforts.

With view of the above, a new mining method called "Thick seam mining by cable bolts" has been developed under an S&T project to mine thick seams standing on pillars.

The method has been tested successfully in 6m thick seam-III of Chirimiri at SECL.

Technique of Cable Bolting

The wire ropes of 19 to 22 mm diameter with safe bearing load over 20 tons under tension when grouted across coal measure formation offered resistance to coal band against sagging and bed separation. A cable bolt as such simulated conventional support of 10-12 tons strength for 6-8 m high roof which can not be achieved even by a timber prop of 30 cm diameter. The anchorage strength of the cable bolts remained undisturbed even after blasting of the roof coal in case of high seams. The technique of grouting cables in the long holes was perfected to yield 8 to 18 tons anchorage load; using grouting and breathing assembly through a wooden plug. The holes were grouted by normal cement mixture with hardcrete for quick installation.

Depillaring Technique

The conventional depillaring approach was adopted in the panels with natural or artificial barriers around. The pillars were split to stooks and the stooks were sliced to permitted height of 3m; leaving 4 to 5m thick coal band along the roof. The development and depillaring galleries were well supported in advance by cable bolts; anchoring the coal band and the immediate roof of 1.5m

Cable botted roof before blasting of the roof coal

thickness as a composite mass. The roof coal was extracted on retreat of the slices by long hole blasting of 1.5m strip so that the loosened coal could be hauled by SDL without exposing the operators to the heightened roof.

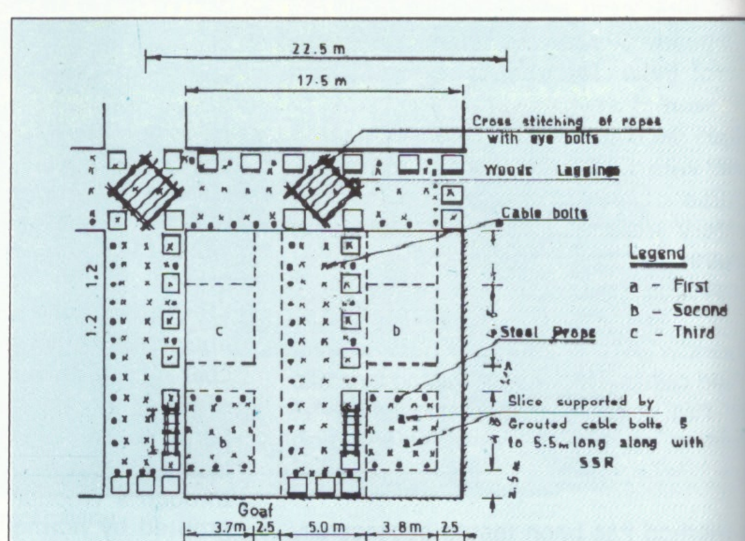
The hanging type support helped in keepi
the floor free of obstruction for t
movement and manoeuvring of SDLs. Th
in effect improved the efficiency of t
loading system and also level of recovery
blasted coal. A full sclae trial was undertak
at NCPH mine where thick No. III seam w
extensively developed on pillars along t
floor. The method has yielded excelle
results in coal recovery, production a
productivity.

Cable bolts hanging in the goaf after the blasting of the roof coal

The comparative statements of conventio
and cable bolting mining method is given
Table -6.

The experiment was successfully repeat
in 6.5m, 7m and 8m thickness of the sea
and under 70m, 103m and 256m dep

Depillaring with Cable Bolt Supports



depth cover and in panel with 38 to 55 pillars to prove the scope of method of mining.

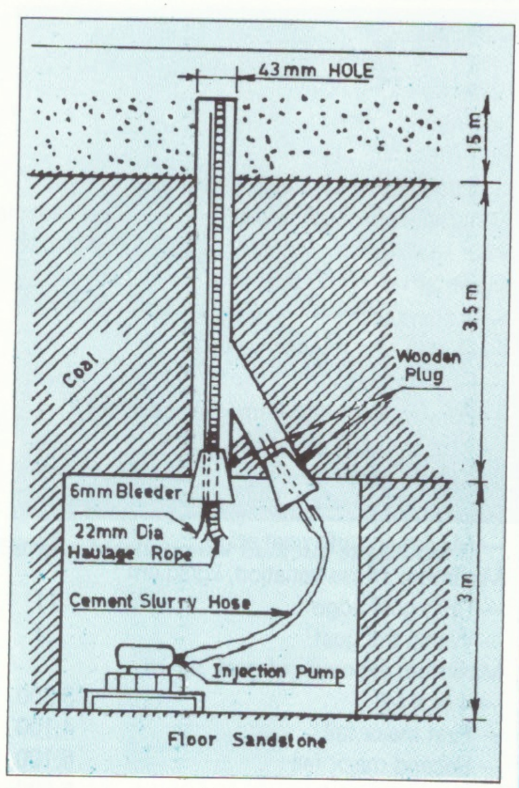
It was observed that the anchorage of the cable bolts invariably above 10 tones even after blasting of the roof coal was adequate to support the whether roof. All the development headings were supported in advance by the cable bolts before the start of depillaring operation. The support system and cycle of mining ensured safety of the workers and the workings during depillaring of up to 8m thick seam under upto 200m depth cover and even under disturbed roof conditions.

The successful trial of the NCPH method of mining has opened new vistas for the exploitation of thick seams extensively developed on pillars in different coal fields of India.

The reserve in thick seams standing on pillars is estimated of be over 1500 million tons under proved and mineable category. Nearly 885 million tons of the reserve in thick seams was amenable to depillaring including [illegible] million tons in Raniganj, 190 million tons in BCCL and 217 million tons in SECL/WCL. This was equivalent to 12000 million tons geological reserve of invariably very good quality coal. The level of recovery of the reserve as per the conventional mining practice was nearly 30% to 40%. this could be increased to 75% by the proposed method and the net profit has improved by Rs. 44 to 71 per ton of coal produced by this method over B&P mining at NCPH Colliery, SECL. The workings have become safe against the occurrences of spontaneous heating because of near complete recovery of the coal.

In view of the established gains, this method is now proposed to be deployed in the following underground mines of CIL :

1. NCPH mine has received permission for depillaring of 4 additional panels.
2. Depillaring of 9m thick major seam at Rajur colliery of Wardha Valley of WCL.
3. Depillaring of 5m thick seam at Nandan colliery of Wardha Valley, WCL.
4. Depillaring of 6.5m thick lower Bachra seam at Churi Colliery, CCL.
5. Depillaring of 6.5m thick upper Kajora seam at Madhusudnapur in Raniganj Coalfield, ECL.
6. Depillaring of 7.2 m thick Gopinathpur Bottom Seam at Basantimala Colliery, BCCL.



Arrangement for full column grouting of Cable Bolt

Table - 6

Geo-mining indices of the experimental domain

Parameters	Panels			
	15	16	17	18
Panel size, mxm	115x135	200x220	180x190	190x200
No. of Pillars	22	43	52	38
Pillar size, mxm	22.5x22.5	25x25	22.5x22.5	30x30
Seam thickness, m	6.5	7.5-8.0	6.5	6.5
Depth cover, m	33-58	37-70	46-103	119-256
Coal reserve within the panel, te	70,000	2,49,000	1,98,885	2,93,000
Total production from the panel, te	53,000	189,240	147,771	179,358
% Recovery	76	76	74.3	61
Cost of production, Rs/te:				
*by cable bolting	417	390	405	—
*by conventional method	461	461	461	—
Profit, Rs/te	44	71	56	—
Manpower per day	124	165	165	135
Productivity-OMS	2.01	2.6	2.8	2.8
SDL Production record				
— Max. Production, te/day	133	187	140	—
No. of cable bolts	—	5,005	5,824	—
Cable bolt size, m	5.0	6–6.5	5.0	5.0
Bolt matrix, mxm	1.2 x 1.2	1.2 x 1.2	1.2 x 1.2	1.2 x 1.2
Bolt anchorage, te	18	>10	>10	>10
General ground condition Disturbance/Joints/Fissure/ Pillar spalling	Not perceptible	Not perceptible	Not perceptible	Perceptible
Maximum convergence, mm :				
— Within the working area	8	18	28	37
— Along the goaf line	26	20	36	97
— Inbye goaf	230	55	58	—
— Convergence rate before fall, mm/day :				
– On the goaf edge	2.4	2.3	2–3.5	3–4.5
– Inbye goaf edge	190	24	15	36
Load on support, tons :				
— Maximum upto goaf edge	11	12.5	7.6	18
Maximum stress variation, kg/sq.cm :				
— Upto goaf edge	11	21	18.2	24
— Within the goaf	21	52	32	31.9
Maximum exposure of goaf, sq. m :				
— Local fall	3,300	2,425	1,100	1,350
— First major fall	4,100	5,900	4,900	5,499
— Second major fall	5,100	2,050	1,875	1,780
— Third major fall	5,500	1,250	2,050	3,900
Subsidence record :				
— Maximum subsidence, m	2.64	2.40	Not measured	Not measured

BLASTING IN MINES

Mining economics depends considerably upon the efficiency of the primary blasts. A proper fragmentation of rocks/coal improves the efficiency of subsequent mining operations, viz. loading, transport, crushing to desired sizes etc. This is essential element of mining was recognised and a research project was initiated to study all aspects of blasting operations and define parameters for reduction of costs. Investigations were carried out by CMPDI at Gapalichak, New Laikdih, Sendra Bansjora, Mining Block - II, Nichitpur (BCCL) among others, leading to evolution of several significant guidelines, which have found application at a large number of mines.

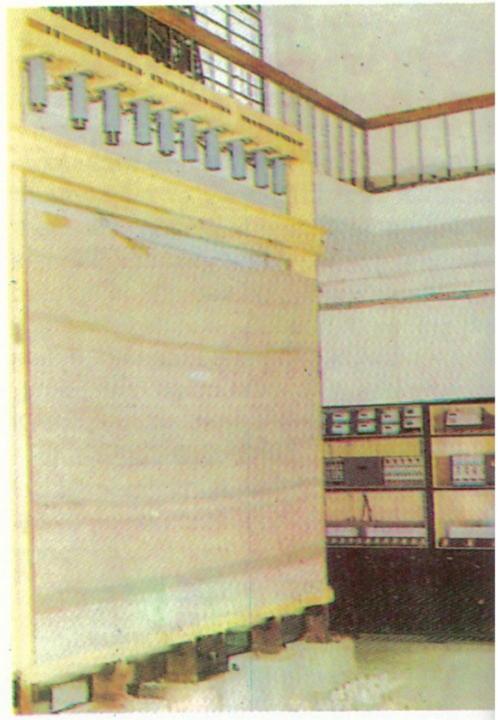
An optimal blasting pattern, depending on the geo-mining conditions, was developed leading to reduction in cost of drilling and blasting. Studies on optimisation of blasting parameters, fragmentation and toe problem etc., were carried out in 61 mines (OC+UG) by CMPDI resulting saving of 15–25% in OC mines and 10–35% U/G mines.

In addition extensive studies were also undertaken to determine the effect of blasting near built – up areas around opencast mines. The studies educed effective techniques of blasting close to such areas. It has become possible to carry out blasting safely as close as 10m from the surface structures against the statutory distance of 300m. Consequently more than 125 Mt of sterilised coal in 60 underground mines have been safely exploited.

Surface blasting near built -up structures

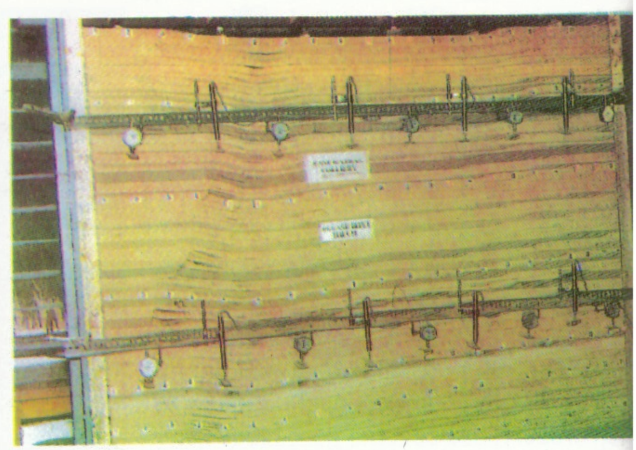
STRATA CONTROL AND SUBSIDENCE

(A) STRATA CONTROL



With increasing depth of workings more complex geo-mining conditions are encountered. This requires a better understanding of the strata behaviour and an accurate estimation of the cover loads. It is however, difficult to predict the strata behaviour. One technique of prediction is modelling, in which working conditions are simulated using equivalent materials for coal and roof/floor strata. R&D investigations carried out by CMRI, Dhanbad have led to the development of appropriate materials for equivalent material modelling, as also a total technique of mine modelling. The expertise developed has been successfully utilised for devising new methods of mining, e.g. Talcher method of mining for working thick seam split in three sections. Wide Stall method of mining for partial extraction of thick seams with stowing under built–up areas, Cross Slicing for working thick and steep seams etc. Some of there methods are being implemented in several mines.

The potential of the technique has been appreciated by the scientific community and similar facilities for equivalent material modelling have been replicated at CMPDI, Ranchi, ISM, Dhanbad, BHU, Varanasi, KSM, Kothagudem etc. The technique is being routinely used to predict strata behaviour under different geo-mining situations.



Equivalent material modelling

Classification of Roof Rocks & Design of Roof Supports

Control of roof strata is an element of utmost importance in underground mines. An appropriate support design system, therefore, is essential for safe and efficient mining operations. With this in view, large scale research investigations wee carried out by CMRI, leading to development of an empirical approach to roof rock characterisation and support design criteria for various categories of roof strata. The empirical approach considers five most significant parameters viz. 1. layer thickness, 2. structural features, 3. rock weatherability, 4. strength of rock, and 5. ground water seepage. Th weightages assigned to the five parameter are 30, 25, 20, 15 and 10 per cent respec vely in order of importance. The sum of th ratings of these parameters give the ratin for the roof rocks, called the "Rock Mas Rating (RMR)". The RMR classifies the ro rocks in five major categories as follows :

RMR	Class	Description
0 – 20	V	Very poor
20 – 40	IV	Poor
40 – 60	III	Fair
60 – 80	II	Good
80 – 100	I	Very good

Correlation were also developed between RMR and the likely rock pressure. The empirical relation obtained between RMR and rock load is :

Rock Load = Span x Mean Rock Density

x (1.7–0.037 x RMR + 0.0002 x RMR x RMR)

Further, research investigations have also helped in laying down guidelines for support design for each of the five following categories of roof rocks.

Class	Recommended support system for development heading
Very poor	Steel arches, rectangular steel support
Poor	(a) Full-column quick setting grouted bolts or resin bolts with W-straps/ channel & wire netting. Props on sides, if required for friable roof.
	(b) Roof stitching in conjuction with roof bolt for temporary roadways.
Fair	Roof stitching supplemented with grouted bolts and wooden sleepers.
Good	Roof bolting only for permanent galleries.
Very Good	Generally support is not required. Support required only in disturbed area.

The recommendations are now being regularly used by mine planners, practising mining engineers and scientific personnel in design of appropriate support system for various situations. Scientific advice has already been rendered to more than 200 mines for appropriate support system under various geo-mining situations. Number of RMR studies and support design framed by CMPDI for the last 3 years is given in Table-7 :

During 1992-95, the CMRI has taken up studies on classification of roof rock to assess the roof support requirement in 35 collieries of CIL.

SECL and WCL have already set up a cell for RMR studies and support design for their underground mines. From the above, it would be seen that there is wide application of RMR studies in all coal producing companies of CIL. Recommendations of Paul Committee on roof supports is also in accordance with the findings of these R&D efforts.

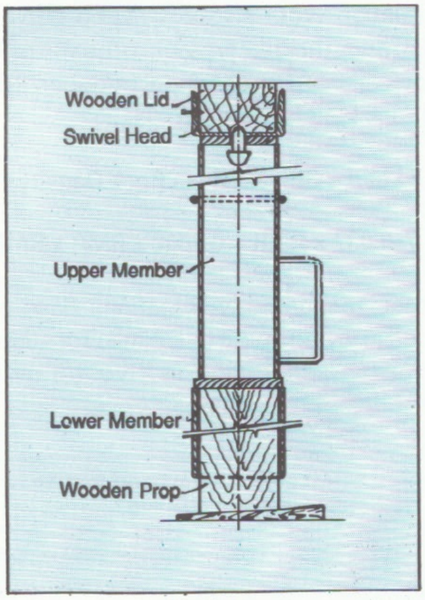
Fibre optic stratascope to determine bedding characteristics of roof rocks

Table 7

Year	*Subsidiary Company of CIL*						
	SECL	***CCL***	***ECL***	***BCCL***	***MCL***	***WCL***	***Total***
1994-95	18	10	13	1	6	1	49
1995-96	—	9	39	12	—	—	60
1996-97	—	26	17	—	5	—	48
					Grand Total		**157**

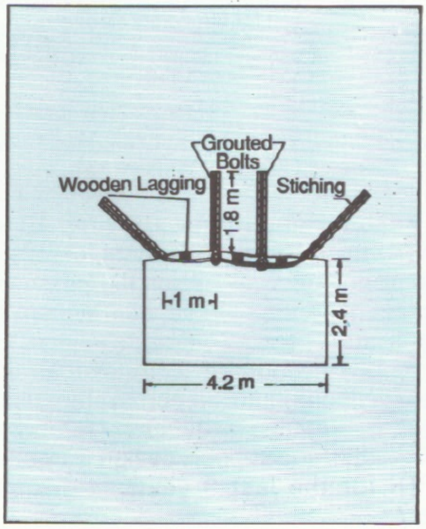
Replacement of Timber by Steel as Roof Support

In addition to the classification of roof rocks and recommending guidelines for support design, another major research initiative was aimed at replacement of timber by steel. Use of timber pit props and bars as underground mine support is still very prevalent. To effect conservation of scarce timber and arrest fast depletion of already thin forest reserves, intensive R&D activites were undertaken to design and develop several types of steel supports e.g., screw props, triangular chock, tubular chock, rectangular chok, pit prop, recoveralbe roof bolt, rope lacing system, split set bolts etc. suitable to Indian conditions. These prototype supports were put on large scale testing under different mining conditions in a number of mines for refinement of final design.



Pit Prop

Combination of wire netting and Roof bolting



Combined system of roof stitching and bolting

Support Requirement in Mechanised Pillar Extraction

In addition, the investigations have also helped in defining the support requirement for mechanised extraction of pillars, and have facilitated the introduction of mechanised depillaring to a very large extent. This is a significant step forward in removing human drudgery in underground mines.

Stowing – Alternative to Sand

When coal is extracted from underground mines voids or goaves are formed. It is sometimes imperative to partially or fully fill the voids to avoid hazards of accumulation of the explosive gases or accumulation of water or spontaneous heating of coal or for protection of contiguous workings or surface features with sand or other incombustible materials. Sand has been the traditional material for backfilling (more commonly known as stowing) of the voids since it was available in abundance in the rivers flowing close to the coalfields.

Over the years due to large scale winning of sand from river beds and poor replenishment these rivers are not in a position to provide the required quantity of sand. As an alternative, BCCL conceived and took up a project to utilise crushed overburden material for backfilling of the voids. A crushed stone plant of 800 tpd capacity at Kankanee Colliery and a Stowing bunker at Loyabad Colliery were installed to carry out field trials.

Trials with different proportion of crushed stone and sand were undertaken at Loyabad Colliery and related scientific investigations were carried out by CMRI. The study revealed that crushed stone either alone or in admixture with sand (in ratio of 1:1) may be used for stowing.

The trials have paved the way for commercial application of crushed stone and of few project reports for crushing / stowing plants have already been finalised. Wider application of this technology is foreseen in the years to come, which should go a long way to limit the dependence on the scarce sand sources.

A view of stowing site

Double compartment for storage of sand and crushed stone

Design of Coal Pillars and Barriers

Design of pillars and barriers is probably the most important factor in Bord and Pillar mining from the view point of safety and conservation. Pillars and barriers were designed hitherto based on Salamon's concept derived from investigations carried out in South African coal mines. The concept, however, did not fully conform to the Indian coal mining conditions. Therefore, research investigations encompassing various geo–mining situations were undertaken, including large number of actual case studies, which led to the development of a numerical procedure for Indian conditions. The relationship evolved also incorporates a long term strength factor, and is now being used for design of pillars and barriers, as well as of chain pillars and stowed or unstowed pillar arrays for Indian conditions. The formula is given as :

Pillar Strength (S)

$$S = 0.27\ \sigma c\ h^{-0.36} + \left(\frac{H}{250} + 1\right)\left(\frac{W}{h} - 1\right),\ \text{MPa}$$

Where,

σc	=	laboratory compressive strength of coal, MPa
h	=	working depth, m
H	=	Depth of cover, m
W	=	Width of the pillar, m.

Investigations in underground

The pillar load (P) can be estimated by tributary area method,

$$P = \gamma H \left(\frac{W+B}{W}\right)^2$$

Stress and Deformation study with vibrat wire stress capsule and Borehole Extensometer

Where,

γ	=	Rock density or unit cover pressure, MPa/m
B	=	Width of galleries, m
L	=	W + B

The pillar size can be worked out from above equations with recommended saf factors as given below :

Stowed pillar arrays	0.6 –
Unstowed pillar arrays	2.0
Chain pillars for panel isolation	1 – 1.
Chain pillars for surface protection while using non–effective width of extraction	2.0
Yield pillar arrays within a panel	0.7 –
Ribs against goaf while depillaring	0.5 –

The above work has been recognis internationally and has benefitted Indian c mining industry immensely by way optimum design of pillars and barriers affecting conservation and safety. T formula developed is being routinely us by planners and designers.

B) MINE SUBSIDENCE

Though some degree of ground subsidence over the mined out or caved areas is inevitable, large and uncontrollable subsidence could create problems of ground stability. Damages to the surface, surface installations caused by subsidence has a specific kind of defrimental impact on the environment. The prediction of subsidence behaviour, therefore, attracted serious attention of mine planners and operators. The aspect on subsidence due to U/G mining is now being taken into consideration the rough subsidence prediction models during mine plaking to minimise its effect on surface and surface installations. The forecast of subsidence will help in advance to plan the effected area for re-use.

No reliable method was available for prediction of subsidence behaviour in Indian coalfields. A number of diverse situations were therefore, studied under the research programme carried out for more than a decade which gave a scientific basis to methodology of coal extraction to have adequate control over surface subsidence. Based on extensive R&D investigations spread over 85 caved and 51 stowed panels it has been possible to formulate guidelines for predicting subsidence behaviour.

The mathematical relationships for determining various subsidence parameters, as also a subsidence predictive model for Indian coalfield have been developed. The predictive model closely estimates the maximum subsidence and other vital parameters. It has also been possible to estimate impact of subsidence on surface features, built up areas and suggest safe limits of subsidence movement for different categories of surface structures. The salient points of the investigations are summaries below :

Maximum Possible Subsidence

Maximum possible subsidence (Smax)

Smax = 0.5 (1+m) e'a'm'h'

where,

Smax — maximum possible subsidence, m
m — rock mass factor
e' — extracted percentage factor.
a' — goaf treatment factor
m' — extraction thickness, m
h' — depth factor.

Surface cracks due to subsidence

The volume of subsidence trough is related to maximum subsidence and area of underground extraction as per the following relationship,

V = 0.527 S.A

Where,

V = — Volume of subsidence trough, m^3
S = — maximum subsidence, m and
A = — area of underground extraction, m^2

Norms for the non-effective width

Rock Mass Factor (M)	Non-Effective Width (NEW)
0.5	0.5h
0.6	0.4h
0.7	0.3h
0.8–0.9	0.2h

Norms for angle of draw for flat seams

Undisturbed overlying rock mass– 25°

Disturbed rock mass upto 42°

Safe limits of subsidence

1. Railway Lines — No movement permitted
   (a) Welded Construction — Maximum strain = 3mm/m
2. Water Bodies — Maximum tensile strain 4.5 mm/m
   — Limiting operating gradient = 1 in 100
3. Buildings — Maximum total elongation or compression = 60 mm (for slight repairable damages)
4. Aerial ropeway and electric transmission high tension Pylons — Strain = 3mm/m
   — Slope to the extent that the displacement of top most point should not be more than one third of the radius of the base.
5. Roads — No stepping due to subsidence

The findings of the above R&D work have already been used to study more than 120 problems involving prediction of subsidence design of underground workings etc. It has been also used to study problems involving extraction of coal seams from underneath and in the vicinity of surface features/built up areas in different Indian conditions.

Subsidence over Chora Colliery, ECL

As a result of these studies, it has been possible to extract more than 25Mt of coal otherwise left as lost, and it is expected that many more million tonnes of hitherto blocked coal reserves may be extracted in near future. The results of the studies have also come handy to mine planners in preparation of Environmental Management Plans (EMP) for the new projects, which have become an essential pre-requisite for clearance from the Ministry of Environment & Forests before sanction by Govt. of India. The subsidence prediction studies carried out by CMPDI for the last 4 years are given below :

Subsidence Prediction Studies

Year	Mine
1994–95	1. Thesgora & Methani Colliery, WCL
	2. Satgram Colliery, ECL
	3. Ramaghundam Shaft Block – II, SCCL
1995–96	1. Kumbharkhani, NCL
	2. Laiyo U/G Mine, CCL
	3. Revised Ramaghundam Shaft Block – II, SCCL
1996–97	1. Tisri U/G Project, CCL
	2. Nehariya U/G Mine, WCL
1997–98	1. Nand U/g Mine, WCL
	2. North Kathara UGP Phase I, CCL

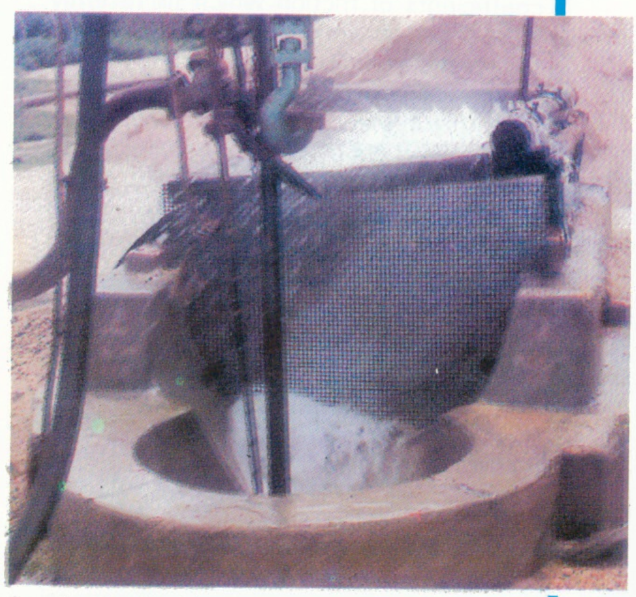
In addition to the above study, subsidence monitoring was also conducted in Shobhapur mines, WCL, Dhemomain, Jhanjra Project and Kottadih Project of ECL. The CMRI is also doing the job of subsidence prediction, monitoring and control. For the period 1992–95, the CMRI has conducted subsidence investigations for 165 panels/workings at 35 mines of ECL, BCCL, SECL and TISCO to develop understanding of subsidence behaviour of coal measures and to prepare norms establishing relationships between subsidence parameters, subsidence predictive models, subsidence control measures and subsidence management methodologies.

STABILISATION OF WATERFILLED UNAPPROACHABLE, UNDERGROUND VOIDS

Commercial coal mining in the Raniganj Coalfield, ECL, was started probably around the present township of Raniganj. As far as is known, two coal seams were worked in this locality at shallow depths and the whole area is now standing on pillars, the galleries being mostly water logged. There had been a few surface subsidences in the past. There are a number of other inhabited areas in the Raniganj Coalfield with similar disturbing situation.

Considerable attention was given to the problem and an alternative was to shift the township to non coal bearing areas. It was found impracticable to shift the Raniganj township to nearby places, as most of the area around is coal bearing. A new township would again block substantial amount of coal in addition to sizeable capital outlay besides adversely affecting the inhabitants. The only alternative to retrive the situation was to stabilise the old water filled workings beneath the present township without disturbing the existing equilibrium.

The old workings being waterlogged, inaccessible and the available old mine plans unreliable, conventional stabilisation technology was ruled out. A possible solution to the problem was studied by Sri H B Ghose, the then Chairman, Asansol Durgapur Development Authority (formerly Chairman, CMPDI), and a technique of hydraulic stowing assisted by pneumatic pressure through boreholes from surface was proposed. The system envisaged conventional hydraulic sand stowing to the borehole floor, whereafter further movement of sand away from mother borehole into the water logged galleries was to be achieved with the air pressure. Laboratory scale model experimentation was carried out at CMRI followed by pilot scale field trials at Ramjeevanpur Colliery, ECL. The trial was quite successful, which helped flush about 17,000 m^3 of sand from a single borehole. This system of stowing tried in waterlogged workings is now being termed as Hydro-pneumatic stowing. Based on the experience gained from this S&T project, ECL has started stabilisation of water filled unapproachable, underground voids beneath the following five localities :

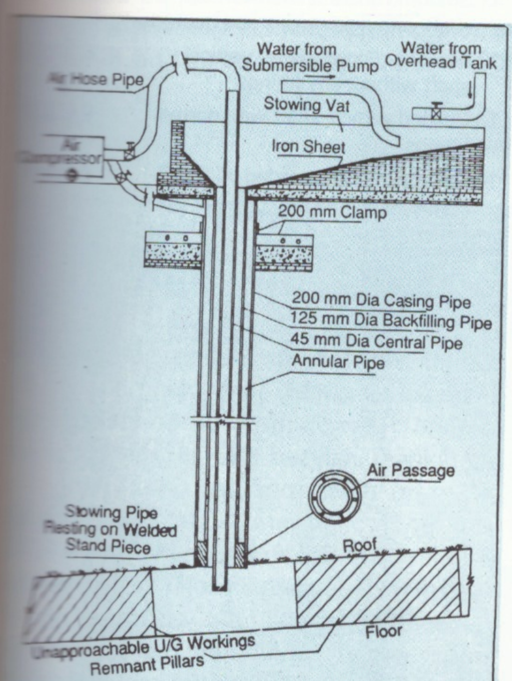


Sand/water flushing arrangement

1. Arun Talkies (Raniganj town)
2. Fatehpur Village (Near Asansol)
3. Borachak Village (Near Asansol)
4. Haripur Village (Near Pandaveshwar)
5. Kumar Bazar Area (Raniganj town)

The trials in these five locations have been undertaken by ECL from CCDA / EMSC funding of MOC.

To further use the experience gained from the S&T scheme and trials at the aforesaid 5 locations, ECL is preparing to stabilise more locations in the Raniganj coalfield.



Sectional view of stowing arrangement Ramjeevanpur Pilot Study Project

MINE VENTILATION

Friction Factor

With the increasing depth of mining accompanied by hot and humid conditions underground efficient ventilation planning and design of ventilation system becomes imperative. Planning and design of an efficient ventilation system needs knowledge about coefficients of friction which till recently were based on work done in mines of Great Britain and several other countries.

With this in view, scientific investigations were carried out by CMRI in various mines in different coalfields of CIL under R&D programme which resulted in defining the friction factors for various types of openings, both supported and unsupported, for effective planning of underground ventilation systems.

The mine openings have been classified in 14 categories representing commonly encountered types in Indian coal mines. The values of friction factor for these are given below.

In addition, the resistance values of the powered support longwall and conventional longwall faces were also established.

These observations were transferred to mining companies and are being routinely used by mine planners, and practising mining engineers in designing underground mine ventilation systems.

Types of openings	Average value of friction factor (K) Kg s^2/m^4
1. Unsupported drivage in coal presenting smooth surface	0.00094
2. Unsupported drivage in coal presenting rough surface	0.00162
3. Unsupported drivage in coal presenting very rough surface	0.00293
4. Unsupported drivage in stone presenting smooth surface	0.00099
5. Unsupported drivage in stone presenting rough surface	0.00184
6. Drivage in coal provided with belt conveyor and sparsely supported	0.00266
7. Drivage in coal supported with three piece timber set.	0.00260
8. Drivage in coal supported with a single row of vertical props along centre line and cog at gallery junction	0.00385
9. Drivage in coal supported with horizontal steel beams	0.00187
10. Drinage supported with steel arches	0.00263
11. Smooth concrete lined vertical shaft with rigid guides and buntons	0.00700
12. Smooth concrete lined vertical shaft without any fittings	0.00069
13. Unlined vertical shaft with normal fittings	0.00233
14. Drivage in coal provided with belt conveyor and heavily supported	0.00505

Sealants for Air Leakage

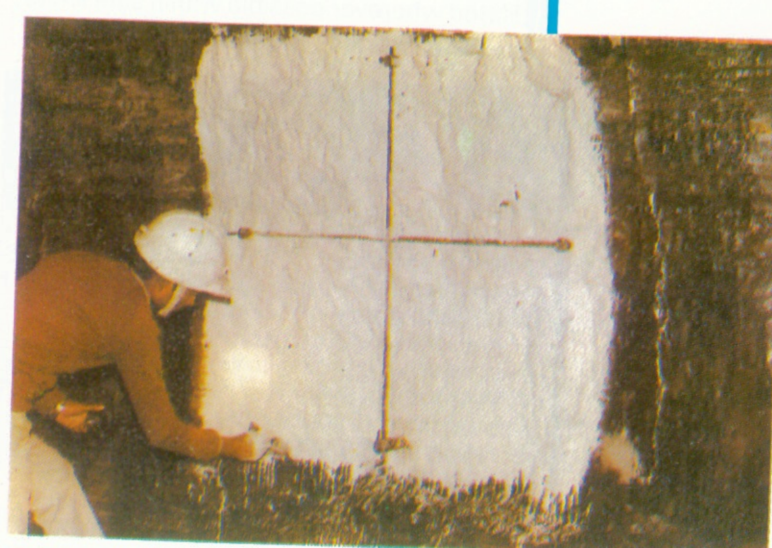
One of the main requirement of any efficient mine ventilation system is coursing of fresh air through specified paths to the work places with a minimum leakage. Leakage of air cannot be entirely eliminated in a ventilation system because of practical constraints. Loose or crushed pillars alongwith acting a solid barrier can cause uncontrollable leakage of air. If such a situation happens to be near a heating zone, it will render the control of heating/active fire a very difficult proposition.

Optimising of various leakage sources could increase air supply to working districts by around 10 percent. Average leakage per stoppings analysed through the computer program developed for quantifying the leakage through various stoppings showed a variation of leakage quantity from 0.12 to 0.75 m^3/s depending on conditions. Practical observation at the field with the help of tracer gas SF_6 indicates the pictures of reality. The variation of the result through computer program STOPLEAK and practical observation are not much (less than 2%)

which is permissible and well within the norms of planning.

In order to control air leakage through gate road stoppings, fractured coal pillars etc. investigations were undertaken to develop a sealant composition, which could be quickly applied on the coal or rock surfaces by mechanical means, and once applied, would remain intact without peeling off or developing cracks over a period of time, thus making the coated surface impervious to air flow.

The R&D activities conducted by CMRI, have led to the development of two types of sealants, one mica based and other latex based. After successful laboratory trials, the efficacy of these sealants has been widely demonstrated at Madhuband colliery, BCCL, GDK-1 Incline, SCCL, Khas Kajora and Madhujore colliery, ECL. These sealants can be applied either manually with a brush or through a specially fabricated pump (Seela machine) and have already found wide application in the coal mining industry in combating mine fires and recovery of fire areas. The mica based sealants is being marketed as "Thermoseal". The sealants have become very effective for mine operations, and a large scale use is foreseen in the coming years.



Sealant application on fractured Coal Pillar

Seela Spraying Machine — Charging of Sealant

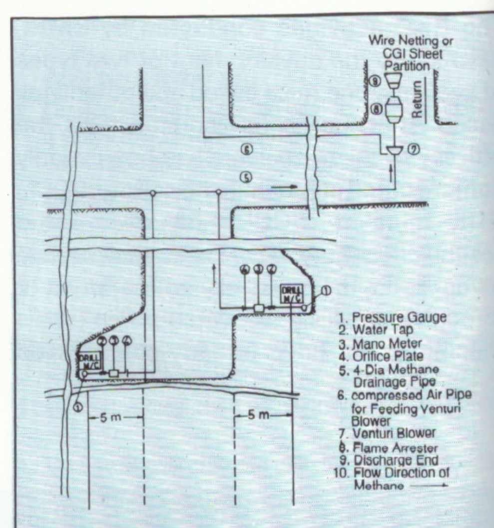
Methane Drainage

Methane (CH_4) or marsh gas is one of the most dangerous gases encountered in coal mines. It forms an explosive mixture with air. It originates from the coal forming material. The occluded gas is give off, during coal winning which is continued even after the initial development.

The emission of the methane gas is normally diluted wherever possible within safe limits by the circulated air current, but there are mines where methane emission is too large to be diluted and kept within safe limits by normal mine ventilation. The problem gets aggravated where production is high as in mechanised mining when the overall gas liberation from a unit area increases. The solution lies in the drainage of methane gas in advance or during the coal mining operatioons. The sustained research efforts during the last decade in this direction within the country have made it possible to achieve some result in the area of methane drainage technique.

Venturii Blower

In the Kargali seam of Sawang Colliery, CCL, methane emission upto 10 m^3/min had been met, while crossing dykes or drilling boreholes. The investigations carried out by CMPDI and CMRI have led to the design, development, commissioning and successful operation of gas drainage system using a venturi blower. Consequently, drivage of headings, abandoned for years due to large emission of inflammable gas, could be started. This expertise can be successfully applied under similar situations in other coal mines.



Methane drainage from long bore holes through venturii blower

Gas Pump

A more critical problem prevailed at Amlabad Colliery, BCCL, a highly gassy mine with presence of contiguous seams, rendering underground operations hazardous. Methane drainage was found to be the only feasible alternative available. The R&D investigations carried out could define the permeability and extent of desorbable gas content of the coal leading to development of a scheme of pre–drainage of methane using a gas pump. A degasification plant has since been installed and commissioned at Amlabad Colliery.

Bio–Degasification

Another method, rather an emerging technology, of dealing with methane gas is by the use of bacteria which is helping in maintaining the carbon cycle of the earth. Laboratory investigations carried out at CMRI have led to isolation of Methanotrophs (a group of micro–organisms which oxidise methane) from soils of marshy land, mine sludge and mine water of gassy coal mines. These micro–organisms can be acclimatised to grow even in 100 per cent methane atmosphere to make them suitable for injection in coal seams. They are found to grow in temperatures upto 45°C and withstand a pressure of even 30 to 35 kg/cm^2 but require near neutral pH and nutrients like salts of mmonia, phosphorous, sulphur, iron, etc, hich need to be replenished periodically.

o–degasification can be carried out either rough gravity migration of bacteria,

— where a rise side sump is used for growth of bacteria

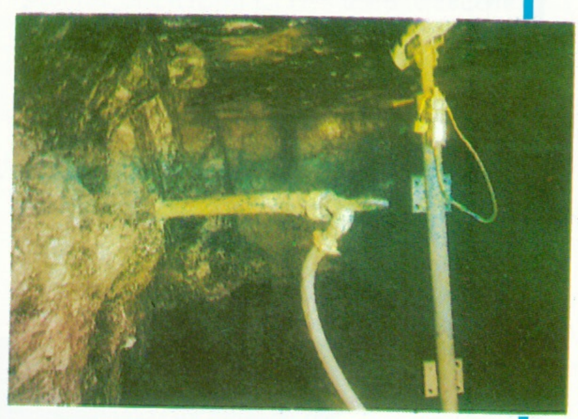
— and its subsequent migration or through injection in boreholes under pressure.

ese systems of bacterial degasification ere successfully tried at Sawang Colliery,

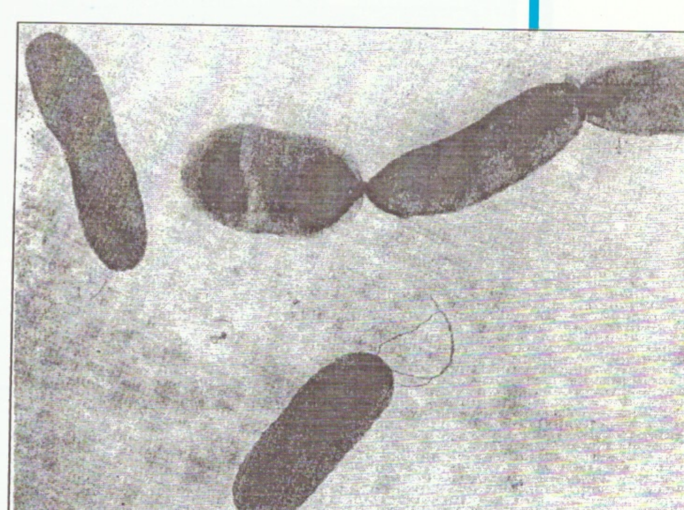
assee and drain pipe assembly, Amlabad, CCL

L, Bhatdee Colliery, BCCL, Amlabad lliery, BCCL, and New Ghusick Colliery, L under an R&D project, and it was found ssible to work highly gassy patches with mplete safety.

These methods of bio–degasification have also found repeat application in a few mines and about 2 Mt of coal have already been degasified in situ under the most adverse gas emission conditions. However, the process being slow, its applicability is limited to small / isolated patches, where other methods of degasification cannot be applied on cost consideration.



Infusion of bacterial culture into Coal Seam



Methanotrophs — Methane oxidising bacteria

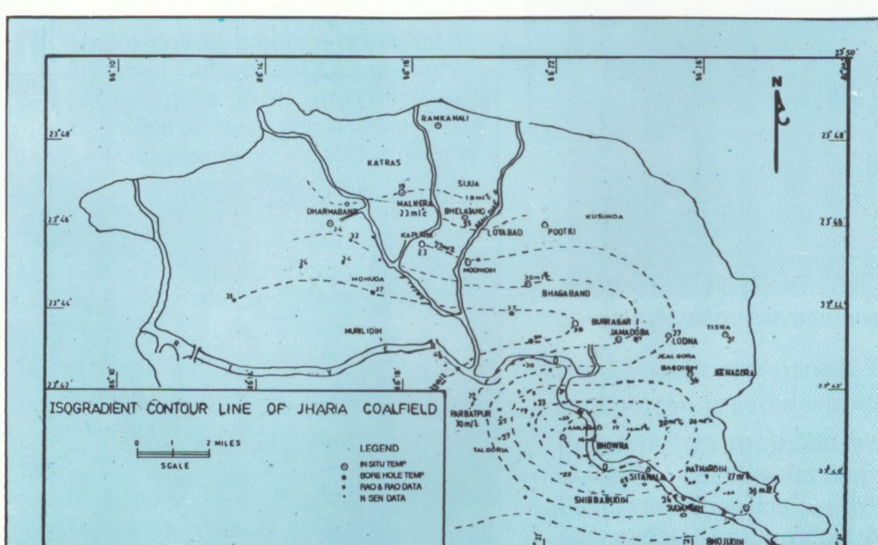
GEO–THERMAL GRADIENT

In situ strata temperature has a direct bearing on underground environmental conditions and its knowledge is thus essential to predict climatic conditions in advance, to enable mine planners and operators to provide for suitable abatement measures. It is also well known that temperature of strata increases with depth and this increase is different in different areas depending on geological and other settings. This is known as geo–thermic gradient and measures in metres per ^{0}C increase. It has been estimated that strata temperature encountered at a depth of around 3000m in Kolar Goldfields may be met at a depth of only 1200 m in Jharia and Raniganj coalfields which are the source of prime coking coal and superior grade non–coking coal in the country. With the exhaustion of shallow reserves a number of deep mines are being planned in these coalfields, and the workings in existing mines are being gradually extended to lower horizons resulting in harsh environmental conditions.

With a view to have effective ventilation and control on climatic conditions, R&D investigations were undertaken to predict the geo–thermic gradient in different parts of Jharia Coalfield and also to elucidate reasons for its variation. The investigations revealed that geo–thermic gradient in Jharia Coalfield varies from 17.3 to 42.0 m/^{0}C. The same for Raniganj Coalfield varies from 41.6 m/^{0}C to 47.2 m/^{0}C. The results of this study have also been projected through thermal isogradient map indicating the variations of temperature gradient in different zones of varying geological settings.

The scientific data so generated under the research programme has been found to be of much use in ventilation planning and climatic control of underground coal mines environment.

Khemtherm Apparatus for thermal conductivity measurement



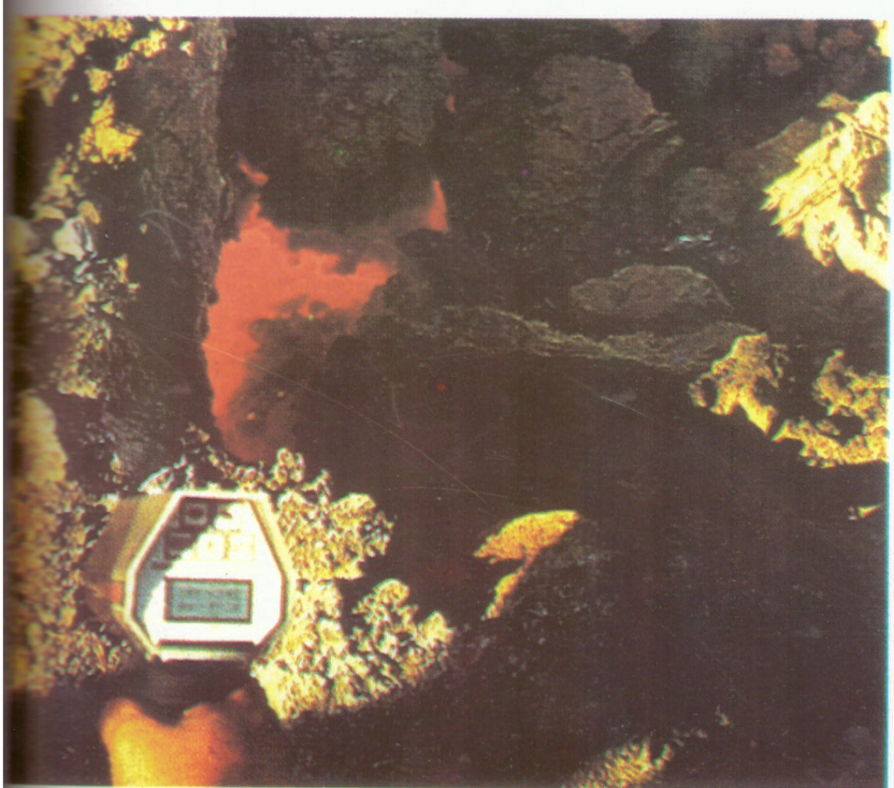
Isogradient contour line by Jharia Coalfield

THERMAL INFRARED REMOTE SENSING FOR MINE FIRE MAPPING

Coal mine fires and its resultant loss and hazards are age–old problems. Jharia Coalfield in Bihar is the store house of prime coking coal in India, primarily used for metallurgical purposes. The deposit in this coalfield has severely been infested by fires over last quite a few decades. The first mine fire was reported in this coalfield in the year 1916. Over the years, number of such fires has increased to an alarming 70 odd locations covering a cummulative area of 17 Km^2 . It is estimated during 1986 that 37 million tonnes of good quality coking coal are lost and 1864 million tonnes of coal are locked up due to fires. Besides, the mine fires are also continuously polluting the environment by releasing large volumes of carbon monoxide and sulphur dioxide gases. Hence, rapid precise mapping as well as monitoring of fires is a pre–requisite for effective implementation of any action plan for fire fighting operations.

The conventional methods of ground/ underground thermometric survey have its own limitations due to both technological and accessibility constraints. In view of the above problems vis–a–vis limitations in the conventional thermometric survey, one research study was taken up by CMPDI in collaboration with NRSA, Dept. of Space, Govt. of India, where successful attempt was made to develop a methodology for thermal studies of coal mine fires using comprehensive remote sensing supplemented by geophysical methods. Daedalus 1268 airborne multispectral scanner of CIL/CMPDI was used to acquire both pre–dawn and day–time thermal data of the project area.

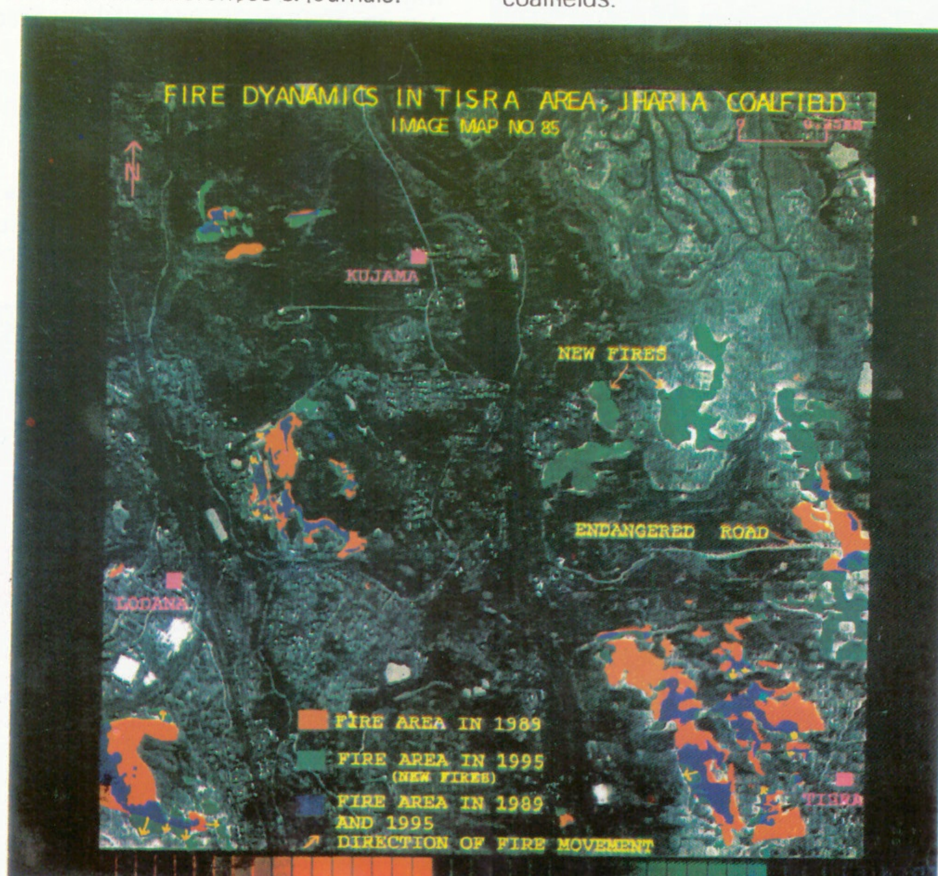
The integrated study encompassing uses of airborne thermal infra–red scanning, ground thermometric and surface magnetic surveys was carried out on a pilot scale over part of Jharia Coalfield covering about 30 Km^2 Mukunda opencast project area during January 1991 to December 1992 based on



Active surface mine fire near Kustore

1989 data. The methodology has proved to be a very effective tool in rapidly acquiring information on the location and intensity of thermal anomalies caused by fires in coal mines. The high resolution scanner data (of the order of 1.2m X 1.2m) have facilitated preparation of black & white thermal IR imageries as well as pseudo colour images, temperature contour maps and 3–D plots of surface temperature distribution. The optimal designing of the above technique for mapping coal mine fires was re–examined and validated with ground truth by a repeat flight coverage during 1995. The airborne scanner data collection of two different cut off periods has facilitated to produce Geocoded product of fire dynamic maps for change detection. During the project study, a unique versatile software 'GEOSCAN' was developed for airborne scanner data rectification. Based on the above project study a total of four technical papers have been presented and published in International conferences & journals.

The technological break through as a whol to tackle any such natural calamity of th kind of spontaneous coal mine fire is itself manifestation of tangible results to b obtained from this research. Th methodology so developed could not onl be utilised effectively and economically fo routine thermal mapping & monitoring, bu also be commercialised straightway by th production units of Coal India Ltd. In fact recently the World Bank Consultants : M/s GAI Inc., USA and METCHEM, Canada, fo their joint venture working for Bharat Cokin Coal Limited in fire mapping in Jhari Coalfield, have utilised the abov methodolgy for the study of the entir coalfield. In addition to mine fires an dynamic environmental studies, the therma IR images and day–time multispectra images which contain lot of usefu information could be of immense use fo developing an up–to–date GIS data base fo evaluation of ground stability in differen coalfields.



Change detection image, Showing mine fire dynamics

MINE FIRES

The very process of underground coal mining creates conditions which are conducive to self–oxidation of coal under certain situations. This self – oxidation in turn may result in heating or even fires. The occurrence of fire, therefore, cannot be totally ruled out in coal mining operations, but can certainly be minimised and controlled. The history of mine fires, thus rightly can be traced back to the beginning of coal mining itself.

Though over the years a number of technologies have been developed to control mine fires, a large number continue to rage unabated, posing a challenge to the mining community. While more conventional methods like, digging, trenching, blanketing, isolating, flooding, etc, were tried in the past to control and combat mine fires, the use of inert gases to render the fire area deficient in oxygen somehow remained unexplored. A couple of research projects were therefore, undertaken to study the methodology to produce and inject inert gas in the fire areas, and determine its effectiveness.

Carbon dioxide/ Inert gas infusion

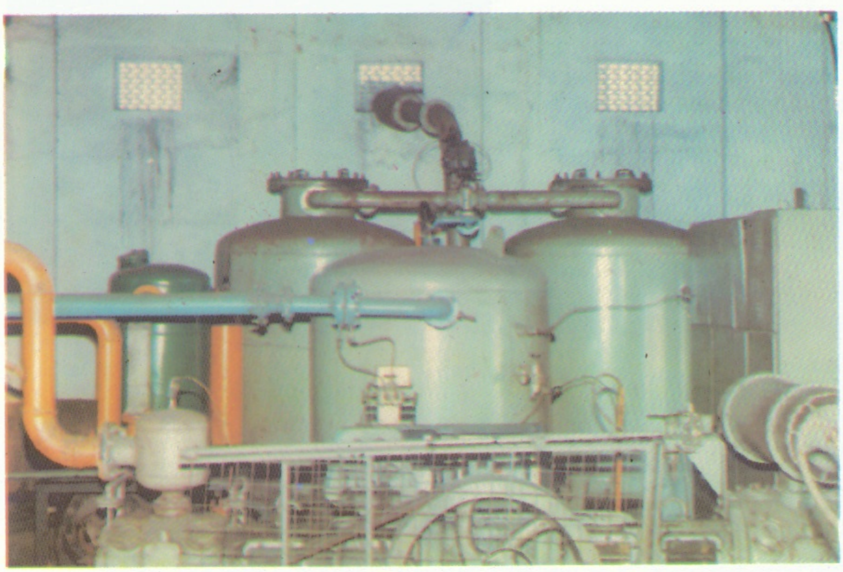
The first ever trial of CO_2 infusion at Sudamdih Colliery, BCCL helped in combating the fire with a minimum risk of methane explosion and thus proved quite effective. This was followed by another trial at South Tisra Colliery, BCCL which helped in controlling a mine fire. In order to overcome the problem of procurement and

Effect of mine fire on land & property ► ▼

transport CO_2 — an inert gas generating plant using kerosene/diesel as feed stock was installed at Laikdih Deep Colliery, BCCL which demonstrated the efficacy of inert gas (CO_2 + N_2) infusion, and could prevent the fire reaching the main transport roadway and save the mine. A coal based inert gas plant utilising fluidised bed combustion process (500 Nm³/hr) has been recently installed and tested at CFRI, Dhanbad. Commercial trials are foreseen shortly.

Nitrogen Infusion

Nitrogen infusion is another gas, which, can be used for making the atmosphere inert in the fire area. This gas also does not have any detrimental phusiological effects. The required quantity of nitrogen gas for the purpose is, however, not available from the industrial gas producing plants in this part of the country. In addition, the transport of liquid nitrogen requires special containers made of cryogenic material. To overcome this constraint, a small nitrogen producing pit head plant (500 Nm³/hr) was conceived, procured and commissioned at Lodna Colliery, BCCL. The plant based on the "Pressure Swing Adsorption" technology uses carbon molecular sieves for separating nitrogen from the atmospheric oxygen. It has been possible to produce nitrogen gas with consistently high purity of above 99%. The effect of nitrogen infusion on arresting spread of underground fire was successfully demonstated at Lodna fire area, BCCL.



Nitrogen infusion plant at Lodhna, BCCL

Following this success, several other nitrogen plants, based on this process are soon likely to be employed for combating underground mine fires.

Foam Application

Development of foam is yet another step forward in the process of underground fire fighting. A sustained R&D effort by CMRI has led to development of appropriate foam composition, methodology of generating foam, and demonstration in mines. The suggested effective foam composition on the basis of large scale investigations is a solution of 0.2% ammonium laurel sulphate along with the required amounts of booster and stabiliser. The solution when sprayed on a net with a pressure of 4 to 5 kg/cm^2 produces foam of required stability which can be moved by air currents of 40 to 100 m/min. This system of foam generation and application is quite simple and may help in making an approach to a fire area in addition to cooling down the fires. Commercial application of foam is foreseen in near future to deal with underground mine fires.

Experimental set-up for generating foam

Foam generation and movement

Foam generation and movement underground gallery

AUGER – CUM – DRILL

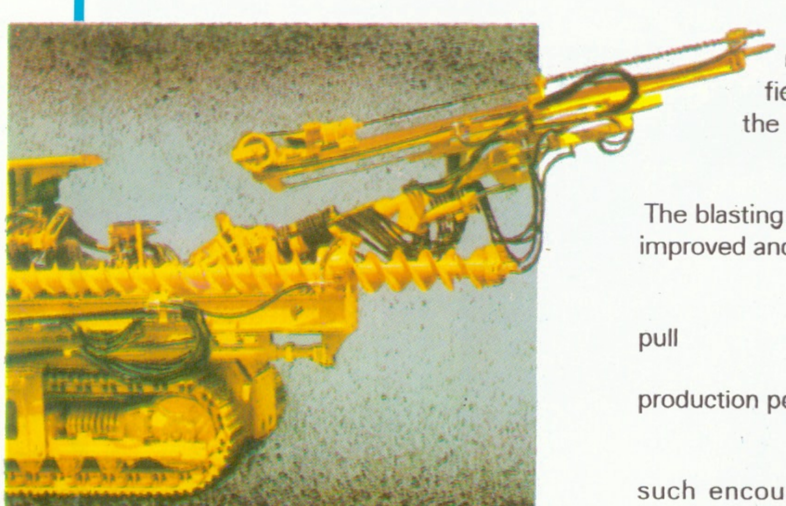
In the conventional Bord & Pillar underground mining, the first development requires creation of a so called "Free face" to ensure safety and a satisfactory blasting pull by explosives. The coal cutting machines employed for the purpose are comparatively slow in operation, and wasteful in manpower. These shortcomings led to adoption of blasting off the solid coal which has its own inherent disadvantages viz. poor fragmentation, and a high explosive cost, apart from the likely damage to the immediate roof strata.

To overcome the above shortcomings, a modified auger–cum–drill machine was conceived designed and prototype manufactured by EIMCO ELECON suitable to Indian conditions. Several important technical considerations involved in the development of the equipment were :

— providing a free face by auguring adequate size boreholes.

— ensuring directional drilling for a better pull.

— effecting economy in manpower due to mechanisation



Auger-cum-drill

The prototype machine was extensively field tested at Churcha Colliery, SECL with very promising performance. It could achieve

Auger-cum-drill at Coal face

average number of rounds/day	—	9 to 10
maximum number of round/shift	—	6
average pull	—	28 to 30 t
powder factor	—	4.2 t/kg of explosive
detonator factor	—	2.15

The favourable performance of the prototype has prompted procurement action by producing companies and 15 machines are already under operation. One more equipment manufacturer has come in the field with an improved design of the machine.

The blasting performance could be further improved and it was possible to achieve :

pull	—upto 2m
production per blast	—above 45 te

such encouraging performance of the machine is likely to pave the way for its large scale application.

COAL BENEFICIATION

Beneficiated Non–Coking Coal for Power Generation

With depletion in availability of good quality power coal and large scale mechanised opencast mining, the ash contentin the raw coal supplies to the power sector has considerably increased. The thermal power industry in the country has tackled the problem of high ash inputs by designing boilers that can burn such coals, but at the heavy cost in terms of lower plant load factor, increased cost of transportation, high level of atmospheric pollution and above all, damaging large land mass for dumping the ash, depleting the already scarce agriculture land which is essential for meeting the food and other needs of a growing population. Coal is a wasting asset and in India, so far the only resource available in abundance for meeting needs of commercial energy, although adding to pollution. Hence, there is a need for conserving this resource through optimal utilisation and use of the same in a manner that will cause least pollution. Beneficiation helps in not only improving performance in use but also in reducing pollution.

In view of above to physically exhibit the advantages of use of beneficiated coal, a research and demonstration project was undertaken, which included a commercial trial of the beneficiated non–coking coal from Nandan Washery, WCL, for a period of one month at the Satpura Thermal Power Plant of Madhya Pradesh State Electricity Board. The demonstration was undertaken jointly by CMPDI, WCL, MPEB and NPC. The demonstration brough out highly encouraging results, major amongst which were :

— Improvement in plant utilisation factor from 73 to 96%;

— Improvement in generation from 3.71 MU/day to 4.83 MU/day;

— Reduction in coal consumption from 0.77 kg/kWh to 0.553 kg/ kWh;

— Elimination of support fuel oil from 5 ml per unit generated to nil;

— Savings in operation of coal mills from 5 units to 4 units;

— Savings in operation of coal mills rejects from 0.35 to 0.031%;

— Reduction in smoke and dust emission from 29.78 gm/m^3 to 17.23 gm/m^3 at ESP inlet and from 1.375 gm/m^3 to 0.299 gm/m^3 at ESP outlet;

— No furnace wall slagging, boiler tube leakage, clinker formation, abnormal erosion;

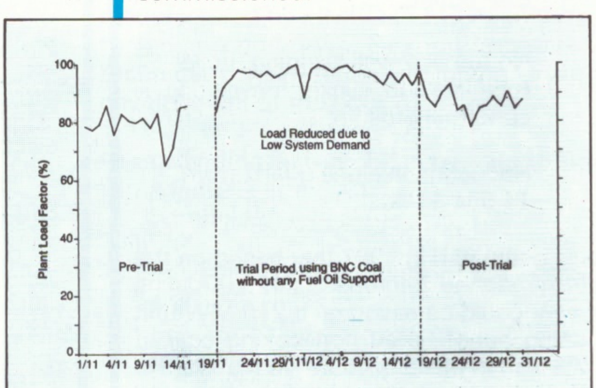
— Reduction in alpha quartz from 14.5 to 11%.

It was estimated in 1987 that based on the aforementioned benefits Rs.426.00 lakhs per year could be saved on a 210 MW unit by using beneficiated non–coking coal of 31.7% ash in place of ROM coal of 39.9% ash. Analysis of the estimated annual savings is as follows :

Sl.No.	Particulars	Savings/expenditure(+/–) in lakhs of Rs. at 96% PUF
1.	Actual increase in expenditure due to use of BNC coal (Thermal Efficiency, freight charges included)	(–) 2067
2.	Additional revenue due to increase in availability generation & reduction in auxiliary energy consumption due to use of BNC coal.	(+) 2117
3.	Savings by reduction of auxiliary support fuel oil consumption.	(+) 314
4.	Achievable savings by reduction of running maintenance, spares and consumables.	(+) 62
	Total	**(+) 426**

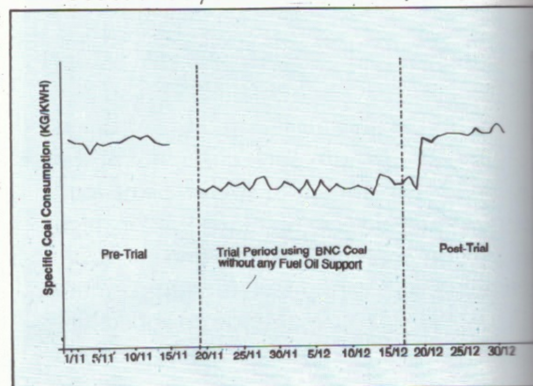
In addition to above, it would provide better environment in the neighbouring surroundings of the power plant due to reduction in smoke & dust emission from 1.375 g/m^3 to 0.299 g/m^3 at ESP outlet. It would also reduce workload for the railways due to reduced coal transportation requirement.

Based on encouraging results of trial run at Satpura TPS coal preparation plant at Piparwar of CCL, Bihar was installed and it was commissioned in 1997. It is supplying beneficiated non–coking coal to NTPC Power Station at Yamuna Nagar, Hariyana & Dadri, UP. The other coal preparation plant for beneficiating non–coking coal at Bina of NCL, Madhya Pradesh has also been commissioned.



Dally Plant utilization factor curve of Satpura T.P.S.

Ministry of Environment & Forest, Govt. o India has made it mandatory through gazette notification that power statio located beyond 1000 Kms, in critica



Curve showing variation in coal consumpti

sensitive & urban areas shall have to us washed coal with ash not exceeding 34 before June 2001.

In view of encouraging test results a Satpura TPS, MPEB has already take initiative to install two washeries fo beneficiating non–coking coal for use Satpura & Korba (E) TPS. Many othe consumers like TNEB, APSEB, KPCL a considering installation of washeries f using beneficiating non–coking coal in th power stations.

Fine Coal Beneficiation

Mechanised mining operations have brough about substantial changes in ROM coal quality such as increased percentages of the dirt, coal fines and moisture which eventually add to the problems of coal beneficiation. The fine coal circuits in the coal washeries are intricate needing close attention and careful operation. The increased fine in raw coal feed to wsheries have also adversely affected the material balance in fine coal circuits in the currently operating plants creating operational problems e.g., jamming thickeners which may effect a complete shut down of the plants for several day Frequent bleeding of the thickeners ha thus become essential. Recirculation of fi laden thckener overflow creates furth problems in the processing circuit.

In the Indian coal washeries the fine co circuits is the least efficient one, resulti in a substantial loss of fine coals along wi effluents and eventually in pollution of th nearby waterways. This problem o additional fines in ROM coal has been th subject of extensive R&D work and has l to several very useful innovations.

Oil Aglomeration

The R&D studies carried out by Central Fuel Research Institute (CFRI), Dhanbad in their 100 kg/hr bench scale plant have established the feasibility of beneficiation of fine coal (0.5mm) by this process. the process is based on the principle of differential wettability of two types of fine particles (macerals and minerals) in two immiscible liquids (oil and water) resulting in preferential migration of macerals to the oil phase and minerals to the water phase. Continuous agitation involved in the process causes macerals in the oil phase to get agglomerated into spherical form whereas the mineral particles remain dispersed in water.

Based on the promising results at the bench scale studies a 2– tonne per hour plant was set up at Lodna Colliery, BCCL initially the trials were beset with a number of problems and required frequent modifications, but with persistent trials, the efficacy of the process on continuous operation could be demonstrated. It was possible to reduce the ash content by about 50% with a marginal loss of carbon in tailings. The oil consumption could be brough down to 8% a vital parameter in overall economics of the process. In addition to beneficiation of coal slurry in washery operation, the process can be utilised for recovery of the coking coal fraction from the washery middlings. The tests carried out with Lodna washery middlings have similar performance parameters as with the coal slurry. The agglomerated cleans from the middlings were found to have much better coking and plastic properties, the maximum fluidity (*Gieseler's tests) over 2000 dpm and the maximum thickness of plastic layer (Saponznikov's tests) as 19mm. These are comparable to the values of a very good coking coal. The agglomerated cleans when carbonised in a pilot coke over, yielded strong coke giving 79.2 and 6.4 as Micum 40 and Micum 10 indices respectively.

The investigations concluded that agglomerates can replace a substantial share of prime coking coal in a blend of coke oven feed.

After the success at Lodna a semi commercial scale plant of 10 TPH has been established at Patherdih Washery, BCCL. The technique offers a likely solution to treatment of fines, when it is fully commercialised especially for recovery of the coking coal fractions from the coal fines/ middlings and difficult to beneficiate coals.

During the trial of this plant with feed of 26% ash at Patherdih Washery, clean agglomerates of 13–14% ash with approx. 18% moisture was produced at average 75% yield. The oil consumption was approx. 8% on dry feed basis, which, however, depends on the fine coal feed characteristics.

Horizontal Agglomeration Cell

The price of clean agglomerates will now be around Rs.2250/te. The price of washed coal with corresponding ash content of 13–14% is around Rs.2400/te. Hence, there will be an estimated benefit of Rs.150 per tonne.

Density Indicator & diaphragm pump

The agglomerated product

Flocculation of Coal Fines and Clarification of Washery Water

To overcome the problem of jamming of thickeners and consequent necessity of their bleeding an extensive research programme was taken up at the Indian School of Mines at bench scale and later extended to pilot plant scale. To ascertain the effect of various floculents their dosages, pulp density etc. settlings tests were carried out on the slurry samples from washeries of BCCL. This was followed by field trials of the identified flocculents in required dosages in operating washeries with the following salient advantages.

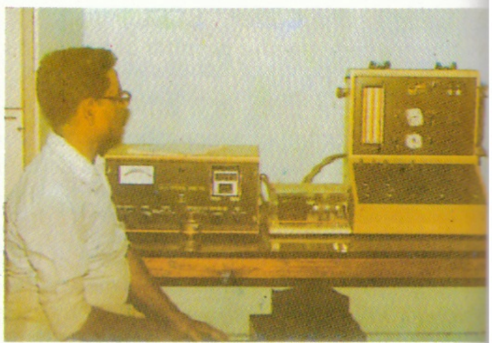
— Settling rate in the thickeners can be increased in the overflow clarity by 33 to 100%;

— The filtration rate can be increased by 30 to 100% with a corresponding reduction in moisture content of filter cake by 14 to 25%;

— The flocculent addition system should provide for real time particles size analysis, pulp density of feed to thickener and automatic adjustment of flocculent dosages;

These have already found useful application in planning and operation of fine coal and dewatering circuits of the present washeries.

Pilot Plant showing high rate thickener — continuous working system



Zetameter for electrokinetic studies and quantasorb for surface area measurement

Barrel Washer Using Coal Slurry as Media

At present Indian coals are washed in heavy media plants using magnetite as separating medium or jig plants or plants with a combination of these two. The cost of operation of the conventional washeries based on the above equipment flowsheet technology which is already quite high was found to be increasing at a rapid rate over the years. There has been a demand for low capacity washeries with low capital requirement and reduced gestation period. Barrel-cum-Cyclone washing with self generated coal slurry as the media requires less capital & operating cost and low power consumption.

The process consists of beneficiation of raw coal (50–0mm) in barrel washer with self generated slurry as media or separator. The barrel floats are crushed and beneficiated by a set of cyclones.

Based on this technology, a 120 tpd modular washery was installed at Lodna, BCCL. Though there were teething troubles during the commissioning stage, sustained R&D efforts leading to certain modifications have led to successful commissioning and operation of the barrel washer. The typical results of plant operation are as follows :

Samples	Wt%	Ash%	Moisture%
Raw Coal	100.0	27.7	3.00
Clean Coal	33.3	17.6	9.45
Middlings	41.2	28.0	7.16
Rejects	18.9	44.8	–
Slurry	6.6	–	–

The major advantages of this process are :

- Low capital investment and operating cost
- No external media (i.e., magnetite etc) required

Close–up of barrel washer

- Simplicity of design with ONLINE adjustment facility
- Easy to operate and control
- Low power consumption, low space requirement.
- Less operating staff/maintenance staff
- Low gestation period
- Flexibility due to Modular structure
- High utilisation factor

The plant is under commercial operation by BCCL since July, 1991. Because of low capital cost and low operating cost four more plants at Dhanbad, Damoah, Kaimur and West Bokaro have came with this technology for beneficiation/deshaling of coal.

Barrel–cum–Cyclone washery does not require any magnetite which means saving of approx. 1000 tons of magnetite every year for the Lodna plant.

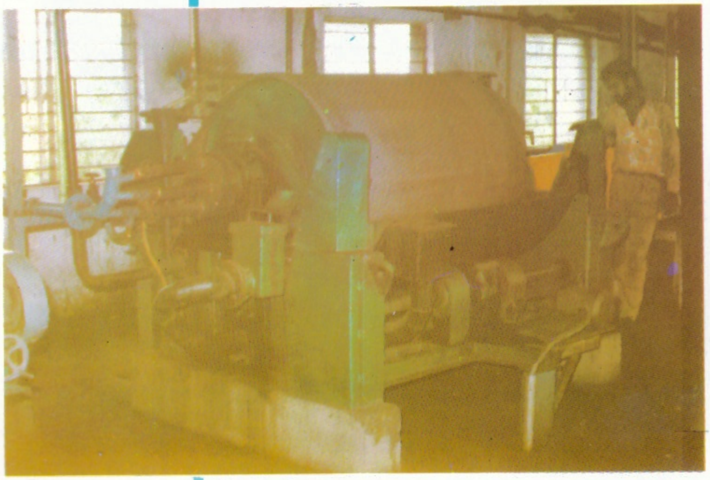
Close–up of pilot plant incorporating barrel washer

Simulation of Different Dewatering Systems

Coal washing in India started in early 50'-60's with the objective of supplying coking coal of required quality to the Steel Sector for steel making. Due to depletion of good quality coking coal, the washery-feed-coal now require crushing to smaller sizes for liberation of coal particles from overall coal matrix. This results in increase in generation of quantum of fines with deterioration in quality. These coal fines are required to be beneficiated for maintaining the overall quality of clean coal.

Selection of cost effective and efficient dewatering system is gaining importance to maximise the recovery of fine coal with minimum possible moisture content in the dewatered products with protection of environment. Considering its importance, "Dewatering of fine coal" has been identified as one of the thrust areas of Research and Development in Coal Beneficiation.

Disc Filter



Drum Filter

For judicious selection of a cost effective and efficient dewatering system a pilot plant consisting of the following modern dewatering systems with state-of-art technology has been installed at Rajrappa Washery to facilitate techno-economic studies in respect of different/allied dewatering systems fo simulation purpose:

1. Disc Filler
2. Drum Filler
3. Screen bowl Centrifuge
4. Horizontal travelling vacuum belt filter
5. Solid Bowl Centrifuge
6. Filter Press

Screen Bowl Centrifuge

Horizontal travelling vacuum belt filter

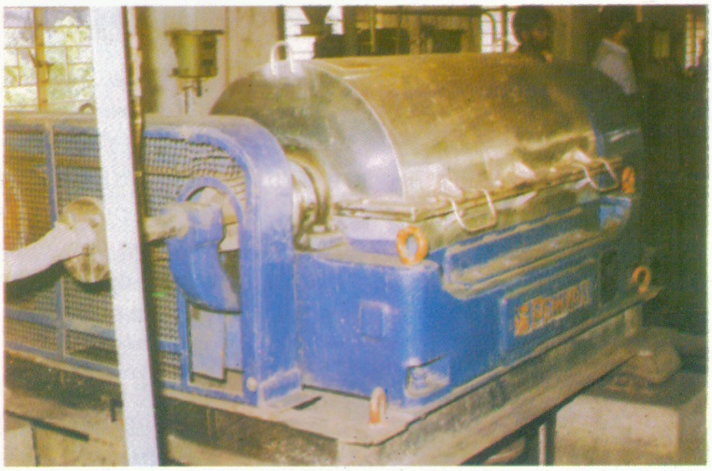
The Pilot Plant has been commi-ssioned in May' 95. The investigation studies were jointly conducted by CMPDI & CCL during May'95 to November'95 with Rajrappa

Washery flotation concentrate and tailings to find out the capability of each dewatering system in the areas of recovery, moisture content in the dewatered product and clarity of effluents. The findings of the study are summarised in table below :

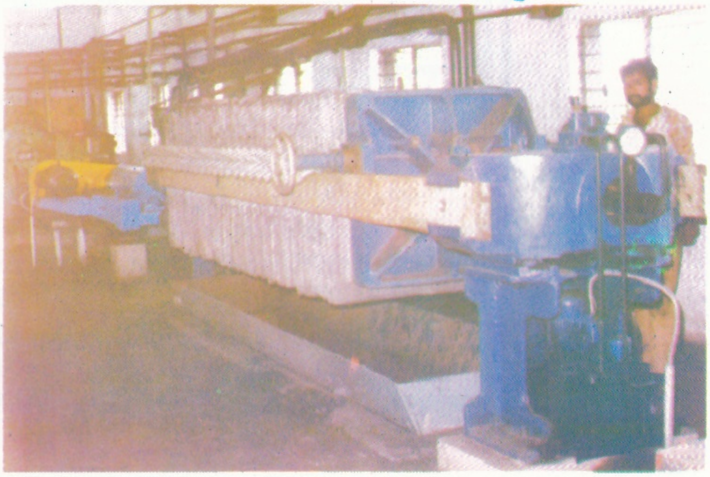
Sl. No.	Name of equipment	Type of slurry	Recovery of product (dewatered) %	Total moisture in the product (Avg.) %	Turbidity of effluent (Avg.) gpl
1.	Solid bowl centrifuge	Flotation tailings	99.65	22.42	1.67
2.	Disc Filter	Flotation concentrate	99.84	19.07	0.85
3.	Drum Filter	Flotation concentrate	98.00	25.05	9.30
4.	Filter Press	Flotation tailings	99.90	28.80	0.25
5.	Screen bowl centrifuge	Flotation concentrate	97.50	14.30	6.00
6.	Horizontal travelliing vacuum belt filter	Flotation concentrate	96.50	25.90	13.30

On the basis of the test results conducted with Rajrappa Washery flotation concentrate and tallings it is observed that screen bowl centrifuge is best suited for dewatering of the flotation concentrate and solid bowl centrifuge for dewatering of flotation tailings.

The Pilot plant can be utilised for testing various coals and generation of data for selection of cost–effective fine coal dewatering system for other coal preparation plants to maximise the recovery of fine coal and to meet the stringent requirement of quality in respect of moisture content of washed coal and to prevent water pollution in the neighbourhood of washeries. Modifications have been considered in the flow schemes of the existing washeries such as Kathara, Rajrappa, Sawang etc. to take care of their fine coal dewatering and environmental problems.



Solid Bowl Centrifuge



Filter Press

COAL UTILISATION

Special Smokeless Fuel (SSF)

Provision of domestic fuel is of considerable importance to which enough attention was not given in the past. This area, therefore, rightly attracted the coal industry's attention immediately after its post nationalisation restructuring. A number of programmes to make available domestic fuels were initiated in the mid and late 70's, the main amongst which were Mechanised Domestic Coke Process for manufacture of Special Smokeless Fuel (SSF) and Coal Agglomerate.

This programme was conceived as a substitute to the primitive method of soft coke manufacture (open Bhatta) which causes serious air pollution apart from loss of valuable by–products.

On reviewing the various technologies for the conversion of coal to domestic coke, the concept of processing of coal (low grade, low volatile with caking index in the range of 8 to 12) in shallow bed continuous de-volatiser with an internally heated system was considered to be the most suitable and a scheme based on this process was thus conceptualised by CMPDI for mechanised conversion of low grade coking coal to domestic coke with a view to :

— obtaining a consistent quality coke;

— obtaining valuable by product in the form of tar;

— minimising air pollution.

The scheme as conceptualised was designed and executed by CMPDI in collaboration with Eastern Carbons, Dhanbad, a private firm, at Mugma, ECL. The pilot plant consisted of four retorts of different capacities i.e., 6, 13, 15 and 30 tonnes per day using sized low grade coking coal of 100 to 30 mm. The pilot plant retorts exceeded their rated capacity during trials runs. The coke yield was found to be around 80% and tar yield 1 to 2%, depending on the volatile matter of coal. The residence time of coal for conversion to coke within the retorts was generally about one hour.

SSF Plant

On continuous operation of the plant all the four retorts gave an optimum output of products (coke and tar) with about 25% recycling of product gas, and the quality of product was found to be satisfactory. The process has since been covered under Indian Patent No. 156855. Since validity of the patent has recently expired, an application has been filed for a new patent. Following the successful demonstration of the process at Mugma there has been a tremendous response from the Indian entrepreneurs for commercial use of this technology. Till now 63 SSF plants have been successfully commissioned by CMPDI.

Retorts in Operation (Coke discharge)

Gas Handling System

The SSF plants already commissioned till 1997–98 are listed below :

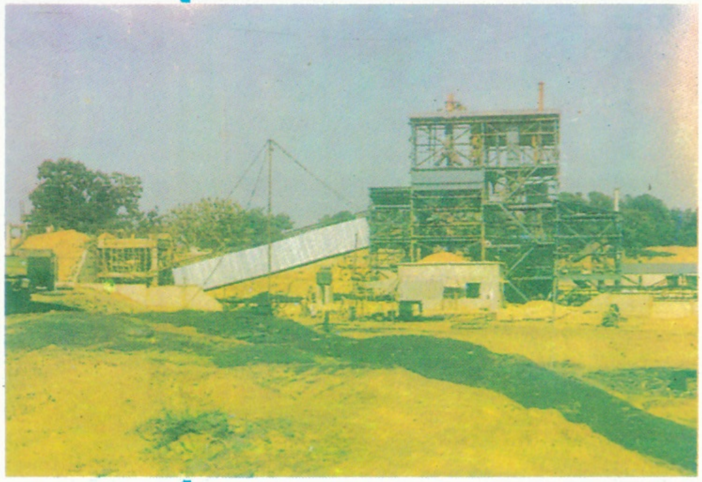
List of SSF Plants Commissioned till 1997–98

1.	Aman Coke Plant Pvt. Ltd.	Aurangabad	BIHAR
2.	Arvind Fuels Pvt. Ltd.	Varanasi	UP
3.	Arya Coke Udyog	Hazaribagh	BIHAR
4.	Ashoka Smokeless Coal Ind. Pvt. Ltd.	Bhabua	BIHAR
5.	Avadh Fuels Pvt. Ltd.	Faizabad	UP
6.	A.S. Fuels Pvt. Ltd.	Rohtak	HARYANA
7.	Babul Smokeless Fuels Inds. Pvt. Ltd.	Madhubani	BIHAR
8.	Bahubali Techno Engineers Pvt. Ltd.	Gaziabad	UP
9.	Baidyanath Ch. & Car. Co. Pvt. Ltd.	Palamau	BIHAR
10.	Balaji Fuels Pvt. Ltd.	Palamau	BIHAR
11.	Basic Fuels Pvt. Ltd.	Giridih	BIHAR
12.	Deshlahara Coke Ind. Pvt. Ltd.	Rajnandgaon	MP
13.	Dhar Coal Products Pvt. Ltd.	Dhar	MP
14.	Drolia Coke Inds. Pvt. Ltd.	Varanasi	UP
15.	Eastern Flames Pvt. Ltd.	Kanpur(Dehat)	UP
16.	Fertico Marketing & Invest. Pvt. Ltd.	Varanasi	UP
17.	Ganga Fuels Pvt. Ltd.	Varanasi	UP
18.	Gautam Coal Works Pvt. Ltd.	Ranchi	BIHAR
19.	Gaya Coke Co. Pvt. Ltd.	Gaya	BIHAR
20.	Gwalior Smokeless Fuels Pvt. Ltd.	Faridabad	HARYANA
21.	Indo Unique Flame Pvt. Ltd.	Nagpur	MS
22.	Interlink Coal Pvt. Ltd.	Bhabhua	BIHAR
23.	Jai Durga Industries	Varanasi	UP
24.	Kakan SSF Pvt Ltd.	Bhojpur	BIHAR
25.	Kalyan Coal Depot. Pvt. Ltd.	Mirazpur	UP
26.	Maa Bindhyhawashini S.Fs. Pvt. Ltd.	Jaunpur	UP
27.	Maa Chhinmastika Coke Ind. Pvt. Ltd.	Hazaribagh	BIHAR
28.	Maa Sharda Coke Mfg. Co. Pvt. Ltd.	Panna	MP
29.	Magadh Smokl. Coking Coal Inds. Pvt. Ltd.	Aurangabad	BIHAR
30.	Maharani Fuels Pvt. Ltd.	Muzaffarpur	BIHAR
31.	Mithila Coal Inds. Pvt. Ltd.	Muzaffarpur	BIHAR
32.	Naman Smokeless Fuels Inds. Pvt. Ltd.	Patna	BIHAR
33.	Pandit Fuels Pvt. Ltd.	Kanpur(Dehat)	UP
34.	Parvati Fuels Pvt. Ltd.	Jaunpur	UP
35.	Pawan Fuels Pvt. Ltd.	Panna	MP
36.	Pritee Fuels & Flames P.L.	Bilaspur	MP
37.	Pushpanjali Coal & Coke Pvt. Ltd.	Aurangabad	BIHAR
38.	R.K. Coal Sales Pvt. Ltd.	Varanasi	UP
39.	R.S. Coke Ind. Pvt. Ltd.	Hazaribagh	BIHAR
40.	Radhey Minerals Pvt. Ltd.	Nagpur	MS
41.	Rewa Fuels	Rewa	MP
42.	Rungta Fuels Pvt. Ltd.	Varanasi	MP
43.	S.J. Coke Ind. Pvt. Ltd.(50–100 tpd)	Hazaribagh	BIHAR
44.	Sawarnrekha Cokes & Coals Pvt. Ltd.	Madhubani	BIHAR
45.	Sawastik Smokeless Coke Pvt. Ltd.	Aurangabad	BIHAR
46.	Shadi Fuels Pvt. Ltd.	Varanasi	UP
47.	Shanti Coal Pvt. Ltd.	Betul	MP
48.	Shiv Domestic Coal Inds.	Patna	BIHAR
49.	Shri Coal Inds. Pvt. Ltd.	Raisen	MP
50.	Shri Marooti SSF Inds. Pvt. Ltd.	Dhanbad	BIHAR
51.	Shri Ram Fuel Pvt. Ltd.	Varanasi	UP
52.	Sohna Construction Pvt. Ltd.	Gurgaon	HARYANA
53.	Solar Carbons Pvt. Ltd.	Nagpur	MS
54.	Solar Smokeless Fuel Pvt. Ltd.	Dehri-on-sone	BIHAR
55.	Subarnrekha Coal Complex Pvt. Ltd.	Allahabad	UP
56.	Super Coke Inds. (5–tpd)	Hazaribagh	BIHAR
57.	Sushila Chem. Pvt. Ltd.	Vaishali	BIHAR
58.	Swastik Cement Products Pvt. Ltd.	Varanasi	UP
59.	Vandana Pvt. Ltd.	Akola	MS
60.	Vidyum Fuel Inds. Pvt. Ltd.	Allahabad	UP
61.	Shri Fuels Pvt. Ltd.	Kunigal	KARNATAKA
62.	Domco Smokeless Fuel Pvt. Ltd.	Aurangabad	BIHAR
63.	Nirdhoom Indhan	Rohtas	BIHAR

Coal Agglomerate

This programme was conceived with a view to finding gainful outlet for low grade, low rank slack coal and providing much needed domestic fuel to areas where such coals are available.

Coal agglomerate is a spherical shaped sized fuel, made out of such coals with suitable binder and which can be conveniently used in conventional domestic Chulla. Coals crushed to desired fineness and mixed with required quantity of binder is agglomerated



Coal Agglomeration pilot plant

in an equipment called pelletiser. The pellets/agglomerates in green condition are soft but attain reasonable physical strength on drying. These are easily ignitable compared to parent coal and give better heat release rate. Strength for handling and transportation can be varied by changing the quantity and type of binder depending on the need including water resistance property. This is basically a low cost fuel to be used in areas near the production centre. This concept has been tried on a pilot plant scale by setting up a 50 tpd plant at Chitra Colliery of ECL. The results of the investigation are quite encouraging. The advantages of this technology may be summarised as follows:

(i) The process can utilise any rank and size of coal. This widens the availability of the resource base for domestic fuel production.

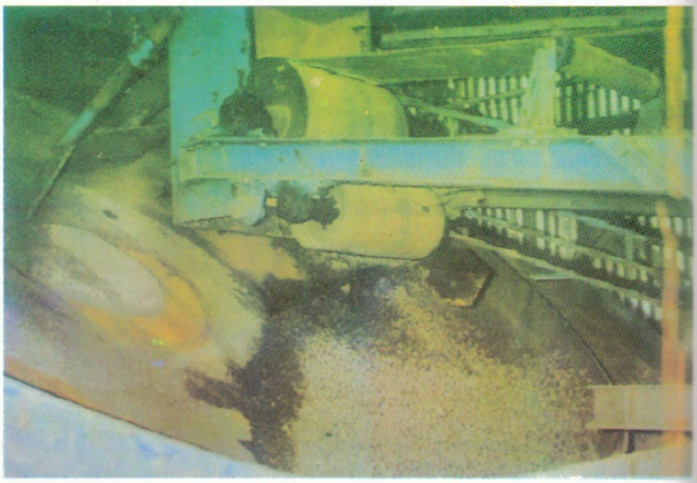
(ii) The technology can be adopted on a small scale with economic viability. For small capacity plants, the only mechanical equipment required are a fine coal crusher and pelletiser. Most of the other jobs may be done manually.

(iii) Even uncarbonised pellets give a bright fire after initial smoke and unburnt portion is negligible due to higher porosity of the agglomerates.

(iv) Such fuels can cater to the demands of lower income group who may tolerate some initial smoke during ignition of fuel bed.

(v) There is no pollution effect from the agglomeration plant.

The process has been covered under patent.



Coal Agglomeration — Inside View

Coal Gas – Replacement to Liquid Hydro–Carbons

Replacement of furnace/fuel oil insmall oil consuming units with coal/coal based fuel is the need of the hour to save on scarce foreign exchange. For such purpose, coal based producer gas plants are already commercially available. These gas producers, however, require sized coal having ash within 30% which is not abundantly available in our country. This situation rightly attracted the coal secto's attention and a project was sponsored to Indian Institute of Chemical Technology (IICT), Hyderabad to set up a small gasification plant (4 tpd coal throughput capacity) based on fluidised bed gasificiation technology for producing fuel gas for replacement of fuel/furnace oil in small industries. This technology is capable of accommodating coal of lower quality that too in slack fraction the availability of which is not a problem.

The gasifier was installed at IICT, Hyderabad and extensive trial runs conducted to perfect the system. The plant has attained the stage of smooth and trouble free operation and the technology is ready for commercial application. The gas produced can also be burnt in hot condition.

Basic designs for units of various capacities ranging from 1 to 5 tpd coal throughput for preparation of detailed design package for such small units have also been prepared. These basic design packages are now available for consumers and may serve very useful purpose of replacement of furnace oil with coal based gas using lower grade coal.

Ash Discharge Arrangement, Fludised Bed Gasifier

Coal Gasification — A Route of Power Generation

In view of the inherent merits of integrated Gasification Combined Cycle (IGCC) system over conventional system of power generation, active consideration is being given on introduction of IGCC system in this country for quite sometime. With a view to identifying a suitable gasification technology for high ash Indian coals, an expert group was constituted by Ministry of Energy in March, 1987. The group after studying various processes in operation throughout the world, submitted a report in January, 1988 with a recommendation to set up a 100–200 MW demonstration IGCC plant in India. As a follows up to this report, two R&D projects were taken up under Coal S&T programme. In the first project various gasification technologies were assessed keeping in view the availability of coal from North Karanpura area. While all the foreign technologies were assessed by the individual process licensors on the basis of the coal quality parameters, it was decided to carry out R&D investigation on moving bed process (indigenously available) with North Karanpura coal. Thus, the second project was taken up for conducting investigation through the 24 tpd moving bed gasification at IICT, Hyderabad and 150 tpd demonstration plant at BHEL, Trichy.

The feasibility of indigenous design installation and operation of high pressure moving bed gasification plant using high ash Indian coals has been established through trial runs conducted at IICT, and BHEL with air–steam and oxygen-steam mode. The trial brought out strong possibility of scale up of such plant. Typical operating data collected from the plant on gasification of NorthKaranpura coal are as follows :

Item	Parameter	Air–steam (10 bar)	Oxygen–steam (23 bar)
Coal	Flow, kg/h	416.3	897.6
Crude gas	Pressure, kg/cm^2	10	23
	Flow, Nw^3/h	896.0	1223.0
	Calorific Value, kcal/Nm^3	1412.0	2648.0
H.P. Steam	Pressure, kg/cm^2	30.8	29.8
	Temp. °C	241	385
	Flow, kg/h	199.2	914.6
Oxygen or Air	Pressure, kg/cm^2	12.6	28.2
	Temp. °C	27	40
	Flow, Nw^3/h	512.0	169.1

Aerial View of Coal Gasification Pilot Plant

Use of oxygen results in higher calorific value of gas, reduced loss of combustible in the ash and consequent high carbon conversion, reduced volume of gases to be handled and reduced size of equipment.

IGCC has been reported to be a viable power generation option for high ash Indian coal. Among the gasification technologies considered for adoption in India, KRW or

A view of Moving bed Pressure Coal gasification plant

similar fluidised bed technologies have been found to be attractive due to high ash content in Indian coals. Moving bed process is also found to be attractive in view of availability of indigeneous capability.

Based on the above successful trials and close interaction with process licensors of different processes of coal gasification, installation of a demonstration IGCC plant is under consideration of CSIR in association with concerned Ministries.

Production of Bio–Fertilizer using Lignite as Carrier Material

A pilot plant of 100 T/A capacity was established and about 21 Tonnes of Biofertilizer strains such as Rhizobium, Azospirillum, Azotobacter, Phosphobacter were produced. The produced strains were tested in the lab, pot culture and field crops. Field experiment was organised in about 2 acres of land in

A full view of installed Biofertilizer Plant (100 T/Annum)

Field experiment using produced Biofertilizer in Backfilled minespoil Maize Crop backfilled areas of minespoil in two locations namely at Mine–I and Mine–II with Green manure crops like Sesbania aculeata and cereal crops like Maize and Finger millet.

Using the produced Biofertilizer a higher biomass production of 13.8 T/ha was achieved in *Sesbania auleata* (a green manure crop) in First crop at minespoil and in Second crop 20.9 T/ha was achieved against the normal agricultural soil with biomass (10–15 T/ha).

backfilled areas with biofertilizer inputs which is a low cost and ecofriendly technology based on Biological Nitrogen Fixation and Phosphate Solubilisation. The above findings therefore assume significance in view of their scope for application in the reclamation of Backfilled areas of Opencast Mines in India. In future the produced biofertilizer will be used for reclamation purpose and rest will be marketed.

Field experiment in Minespoil

(a) using Biofertilizer, a well grown Maize Crop with COBS

(b) a closer view of COB in the plant

In cereal crop Maize yield of about 5.7 T/ha was achieved against normal agricultural soil (5 T/ha) and in Finger Millet 2.57 T/ha was achieved against normal agricultural soil (3–4 T/ha), on application of Biofertilizer. It is concluded from the field trials on application of produced Biofertilizer in minespoil has increased the biomass/yield several folds than control.

The findings of the present study have conslusively established the scope of reclamation of the

Green Manure Crop Sesbania aculeata established in Minespoil field trials with Biofertilizer

Humatic Matter from Lignite as Soil Conditioner/ Composite Fertiliser

Humatic matter can be used as a soil conditioner which modifies the physico–mechanical properties of soil and stimulates plant growth. Apart from this humic acid as a precursor of coal is the basic material from which a number of commercially important chemicals like,

Effect of humatic matters on corn growth

Lignin, its derivaties and mud additives (Caustic Lig, Chrome lignite, Lignin Sulphonate, Resinex etc.) can be obtained. In Youger types of coal like lignite the humatic substance forms a greater part of coal bulk. The Neyveli Lignite contains about 60% (moisture and ash free) humic acid.

Considering the importance of humatic matter as a plant growth stimulant Neyveli Lignite Corporation (NLC) undertook a research study in collaboration with Mining Institute of Belgrade, Yogoslavia. The research study concluded that :

- Lignite can be solubilised by causticisation with NaOH at ambient pressure. Higher pressure is to be applied if causting potash (KOH) is used.

- Efficacy of the humatic matter as a plant growth stimulator has been proved by growing Indian corn upto the third leaf stage.

After having established the feasibility of extraction of humic acid from lignite; NLC is actively considering setting up of pilot plant for the extraction of humic acid for use in various processes developed or under development. These include :

- Extensive testing of applicability of humic acid as an organic fertiliser.

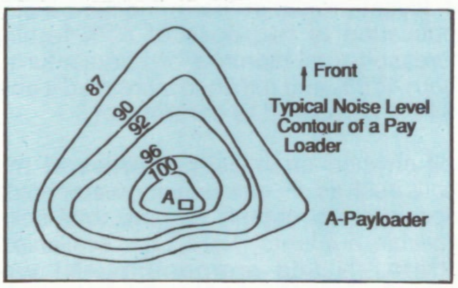
- Feasibility of nitrogen fixation in humic acid to increase its biological activity for composite low cost fertiliser.

- Formulation of new projects to manufacture micro–nutrients using humic acid and trace elements.

- Laboratory tests to pelletise lignite char fines using humic acid as binder, obviating expensive binders to obtain a relatively low – cost agglomerate coke.

Noise – Environmental Pollution

Noise production is a part of any industrial activity. Noise levels beyond a certain limit have an adverse effect, and cause environmental pollution of a significant nature. In order to inhibit the effect of pollution due to noise, an extensive R&D study was carried out by CMRI to estimate the noise dose to which different categories of workers remain exposed during their work. The study also identified the noise sources. The R&D study helped define noise levels in different mining activities. It was observed that most of the machines emit noise beyond the threshold value of 90 dB, and become a source of pollution. The data base generated during studies offers considerable scope for the coal producing companies to interact closely with the manufacturers of the machines to improve their design for reduction in noise level.



Noise profile of pay loader in drilling opencast mining

Noise level measurement in drilling operation in opencast coal mine

Revegetation of Mine Spoil

Ecosystem destruction by Opencast coal mining is an inevitable product of the process of industrialisation and civilisation. During mining, not only the vegetation is destroyed but there also occurs loss of soil both in pedological and biological senses. Flora & Fauna, hydrological relations and soil biological systems are drastically disturbed. Huge amounts of infertile overburden materials are dumped on adjacent lands in addition to pit scarred landscape. When rock soil plant stability circuit is disturbed by mining, ecological chaos takes place. Generally, mine spoils are physically, chemically and biologically recalcitrant medium for plant growth. The drastically disturbed ecosystems are extremely vulnerable to future anthropo-genic global change.

Natural recovery of mine spoils is a slow process and traditional methodology of afforestation often proves inadequate. Thus, there is a need to develop and test appropriate methods for speedy reconstruction of the total biotic community. Seeding or planting of plant species belonging to different life forms speeds up successor, thereby accelerating the process of recovery. The multistratal vegetation is desirable for creation of diverse ecological niches and for soil and water conservation.

In view of the above, the Ministry of Coal has sponsored a research project on Revegetation of Mine spoil with the

A general view of the slopes around the rain-water harvesting tank planted with fruit trees at Jayant Project objectives a) to understand the ecological changes during vegetation on mine spoil, and (b) to develop ecotechnology for accelerating the revegetation of mine spoils by using biological resources.

An intensive ecological study of revegetation of mine spoil at Jayant and Bina project in the Northern Coalfields Ltd., Singrauli was initiated in 1993 with the various revegetation models set – up under this project. These models are : tree monoculture seeded with grasser and legumes; tree monoculture seeded with crop plants; tree monoculture with ground seeding and fertiliser applications; and tree mixed culture seed with grasses and legumes.

Tree monoculture experiment at Jayant project comprised eleven tree species. Ground seeding was done with stylosanthes hamata, Heteropogon contortus and pennisetum pedicellatum. Fastest growing species in terms of height was Albizia lebbeck closely follwed by Dalbegia sissoo and Gmelina arborea. In terms of diameter growth, Gmelina arborea and Albizia lebbeck were the fastest growing species and were followed by Acacia catechu, Dalbergia sissoo and Azadirachta indica.

At Bina project tree monoculture comprised eleven tree species of which four were different from those at Jayant project. Ground seeding was done with stylosanthes humilis. Fastest growing species in terms of height was Dendrocalanus strictus followed by Albizia lebbeck, Termindia arjuna, Emblica, Officinalis and Pongbamia pinnate. In terms of diameter growth, Terminalia arjuna was the fastest species and was follwed by Pongbamia pinnate, Tarmarindus indica, Azadirachta indica, Emblica officinalis, and Albizia lebbeck.

At Jayant project in the monoculture plots, application of half dose of NPK fertiliser increased total biomass of Pennisetum by about 479% and full dose increased it about 1044% compared to control plot.

Soil physico–chemical properties of mine spoils such as p^H, bulk density, water holding capacity, total organic carbon, total soil N, available nutrients ($NaHCO_3$ – available Pi, nitrate –N and ammonium –N) were estimated at Jayant for plots planted to different species. Soil microbial biomass, C, N and P Nitrification and total N – mineralisation rates were also quantified. Compared to native non–legbuminous species plots, showed greater C, nitrate –N, ammonium –N, N–mineralisation rate, and microbial biomass C, N and P content. Except for organic C, no marked differences were found between exotic legumes and non–legumes plots. These findings suggest that native legumes are more efficient in bringing out differences in soil properties than exotic legumes in the short–term .

Sharea robusta (4-yr old) plantation raised by State Forest Research Institute at Jayant project registered 1.9 t ha^{-1} yr^{-1} net production

Albizia lebbeck (4-yr old) plantation raised by SFRI at Jayant project registered 11.8 t ha^{-1} hr^{-1} net production