VAN DE VALL, M. *Labor organizations: A macro- and micro-sociological analysis and comparative basis.* Cambridge; Cambridge University Press, 1970.
VAN KNIPPENBERG, A., & VAN OERS, H. Social identity and equity concerns in intergroup perceptions. *British Journal of Social Psychology,* 1984, *23,* 351-363.
WALKER, I., & MANN, L. Unemployment, relative deprivation and social protest. *Personality and Social Psychology Bulletin,* 1987, *13,* 275-283.
WALKER, I., & PETTIGREW, T. F. Relative deprivation theory: An overview and conceptual critique. *British Journal of Social Psychology,* 1984, *23,* 301-310.
WHEELER, L., REIS, H. T., & BOND, M. H. Collectivism-individualism in everyday social life: The Middle Kingdom and the Melting Pot. *Journal of Personality and Social Psychology,* 1989, *57,* 79-86.
WILDER, D. A. Predictions of belief homogeneity and similarity following social categorization. *British Journal of Social Psychology,* 1984, *23,* 323-333.
WOLF, S., GREGORY, W. L., & STEPHAN, W. G. Protection motivation theory: Prediction of intentions to engage in anti-nuclear war behaviours. *Journal of Applied Social Psychology,* 1986, *16,* 310-321.
WRIGHT, S. C., TAYLOR, D. M., & MOGHADDAM, F. M. Responding to membership in a disadvantaged group: From acceptance to collective protest. *Journal of Personality and Social Psychology,* 1990, *58,* 994-1003.

BIOGRAPHICAL NOTE

CAROLINE KELLY is a Lecturer in Psychology at Birkbeck College, University of London. Her main research interests are in group processes, particularly social identity, intergroup relations, and collective action.

JOHN KELLY is a Senior Lecturer in Industrial Relations at the London School of Economics. His main research interests are in trade unions, industrial conflict, and job re-design.

Human Relations, Vol. 47, No. 1, 1994

Social and Technological Characteristics of Coal-Face Work: A Temporal and Spatial Analysis

Jonathan Winterton[1,2]

This paper offers a re-evaluation of the Tavistock studies of coal mining during the 1950s by analyzing their relevance to the social and technological characteristics of coal-face work before and after the studies. The historical analysis draws upon documentary evidence, while the study of contemporary changes in coal-face work has involved a decade of interviews with miners, mining engineers, managers and union officials, supplemented with underground visits. The specific recommendations of the Tavistock work are shown to have been made redundant by technological change, but their wider relevance is demonstrated both in relation to understanding earlier technological developments and in identifying weaknesses in the present organization of face work. Had the lessons of the Tavistock experiments been incorporated in the design of new technologies of coal production and the organization of face work, more human-centered work could have evolved without sacrificing improvements in productivity.

KEY WORDS: coal face; technology; work organization; human factors.

INTRODUCTION

It is more than 40 years since *Human Relations* published the influential sociotechnic analysis of coal-face work by Trist and Bamforth (1951). During this time there can be few students of industrial sociology who have not been introduced to Tavistock action research through that article, and the fuller account (Trist et al., 1963) must rank among the great classics. Part of the study was republished as recently as 1989 (Trist, 1989), such is the significance, persuasiveness, and durability of the argument.

The first study by Trist and Bamforth (1951, p. 5) noted that in the recently-nationalized coal-mining industry there were worsening problems

[1]Management Centre, University of Bradford, Emm Lane, Bradford, West Yorkshire BD9 4JL U.K.
[2]Requests for reprints should be addressed to Jonathan Winterton, Management Centre, University of Bradford, Emm Lane, Bradford, West Yorkshire BD9 4JL U.K.

0018-7267/94/0100-0089$07.00/1

of "low productivity despite improved equipment and . . . drift from the pits despite both higher wages and better amenities." Trist and Bamforth believed that these problems stemmed from "social shortcomings in the longwall method" of mining because "innovations in work organization at the coal-face" had resulted in increased productivity, group cohesiveness, and individual job satisfaction, as well as decreased sickness and absentee- ism (ibid. pp. 3-4). The hypothesis was tested by undertaking a "detailed appraisal" of the social characteristics of longwall mining compared with pre-mechanized mining. As a result of this analysis, they concluded that if "socially-ineffective structures at the coal-face" continued, so would prob- lems of morale, recruitment, and labor turnover (ibid. p. 37). The effective solution of these difficulties would require establishing forms of work or- ganization centered on "restoring responsible autonomy to primary groups throughout the system and ensuring that each of these groups has a satis- fying sub-whole as its work task, and some scope for flexibility in work pace" (ibid. p. 38). In subsequent work, Trist et al. (1963) experimented with alternative arrangements and confirmed that "composite methods," employing mechanized longwall technology in combination with work or- ganization which retained elements of the hand-got era, produced superior results in terms of productivity and various indices of worker morale.

The major theoretical contribution of the Tavistock Institute of Hu- man Relations was in the development of an open sociotechnical systems model of industrial organization, while the major empirical contribution concerned the analysis of social behavior and functioning of industrial work groups. These contributions were nowhere more evident than in the coal- mining studies, which differed methodologically from most other Tavistock work in emphasizing research rather than consultancy and in adopting a comparative rather than case study approach.

The Tavistock studies, like the work of Woodward (1958), Blauner (1964), and others, represented a departure from focus on the human re- lations climate to a consideration of technology as a major factor influencing industrial behavior. While some writers who emphasized tech- nology were guilty of technological determinism, this was never the case with the Tavistock analyses because technology was always seen as influ- encing behavior only through its effect on work organization. Moreover, the Tavistock studies made two distinctive innovations in the debate on the relationship between technology and social structure. The first was in challenging the classical view that task specialization was necessary for in- dustrial efficiency, two decades before Braverman (1974) offered a Marxist critique of Taylorist work organization. The second was in demonstrating the choice of alternative forms of work organization which were available for a given technology, making possible the optimization of social and tech-

nical systems. As Trist (1968, p. 354) later noted, "the studies in the British coal industry. . . provided the first detailed empirical evidence of the su- periority of certain forms of work organization over others for the same technological tasks."

The Tavistock study of coal-face work was confined to a single tech- nological era but drew its major strength from incorporating earlier experience. Nevertheless, the substantive recommendations rapidly became redundant with subsequent technological changes in British coal mining. This paper offers a review of technological developments in coal mining and their interaction with social factors, incorporating both temporal and spatial differences. The analysis will provide a contextual setting in which to situate the work of Trist and colleagues, and will assess the relevance of their study outside that setting.

The significance of the Tavistock coal mining studies should not ob- scure deficiencies in the analysis which the present paper seeks to address. First, technology was inadequately defined in the Tavistock work because the contrast between traditional and longwall mining conflates two distinct dimensions, contrasted in the present paper as the material technical base (hand tools or machines) and the technique of production (shortwall or longwall). This confusion has been perpetuated both in the extensive re- prints of the 1951 paper (e.g., Burns, 1969, pp. 331-358; Pugh, 1971, pp. 345-369) and in secondary accounts (e.g., Silverman, 1970, pp. 113-114), even where these have embodied theoretical critiques (Brown, 1967, pp. 46-49; Rose, 1975, pp. 177-180). Second, there is the implicit assumption in the Tavistock work that an enterprise's primary task is consensually de- termined, or that such consensus can be reached. As a result, Brown (1967, p. 39) noted the absence of "an awareness of the conflict, at the social not the psychological level, which is inherent in relations between employers and workers."

This paper distinguishes six phases of coal-face work in British deep mining in terms of three dimensions. First, there is the *material technical base,* the physical instruments of labor, or hardware, employed. Second, there is the *technique of production,* the way in which work is undertaken or particular tasks carried out. These two dimensions can be thought of as the constituents of "technology." Third, there are social factors which may be collectively described as *work organization,* involving such aspects as the division of labor, skill, and autonomy. When the conflictual nature of em- ployment relations is taken into account, the balance of power between labor and management (itself subject to a whole variety of economic, po- litical, and social factors) may be seen as a major influence on strategies of management and labor in relation to technology and work organization. Changes in technology or work organization may facilitate or be facilitated by changes in the balance of power between the forces of production. Other factors, of course, form part of the wider context in which the work takes place. For example, the *subject of labor,* coal, is itself a physical factor, enormous variations in which (depth, seam thickness, quality, dirt, water, gas, etc.), have a major bearing upon technological and organizational choices. If attention is focused on the point of production, the three dimensions, material technical base, technique of production and work organization, are sufficient to establish a simple typology of coal-face work. The three dimensions are interrelated; each is constrained, but not determined, by the others.

It is customarily assumed that coal-face work in Britain passed through four phases: hand-getting, mechanized mining, power loading, and advanced technology mining (Burns et al., 1984a; Penn & Simpson, 1986). This view is only partially correct. The first phase is distinguished from the second and subsequent phases in terms of the material technical base. Hand-getting involved only picks, shovels, and wedges, whereas mechanized mining involved the use of various coal-cutting machines. However, both hand-getting and mechanized mining could employ two alternative techniques of production: short-wall mining, working a number of small areas of coal; or longwall mining, getting coal from the entire length of a coal face.

There were thus four major phases in the development of the labor process at the coal face before power loading, and six in all to date. Hand-getting gave way to mechanized mining and short-wall was superseded by longwall, but there was no single chronology of development from one stage to the next, as Fig. 1 shows (Heycock & Winterton, 1989). From the earliest hand-got short-wall mining, the labor process could develop to machine-cut short-wall or hand-got longwall, and thence to machine-cut longwall, or on occasion directly to this without passing through the intervening stages. Similarly, when power loading was introduced to longwall faces, a few of these had not been mechanized previously. New collieries would generally adopt the most modern mining practices, but there was considerable diversity between coalfields and, before nationalization, between companies. Moreover, there were variations of each of the phases of the coal-face labor process as a result of different geological conditions and historical traditions of individual collieries. Nevertheless, with these qualifications borne in mind, it is possible to analyze the distinguishing characteristics which typified each phase of coal-face work.

HAND-GOT SHORT-WALL MINING (HGSW)

The earliest mining of the best and shallowest seams, once surface coal from outcrops was exhausted, usually employed a method known variously as pillar and stall, bord and pillar, or room and pillar working. First, a parallel series of narrow headings (small tunnels off the main roadway) driven into the seam would be connected by perpendicular cross-headings, removing about 25% of the coal and leaving panels of coal 50–100 meters square. The second stage involved driving roads (bords) from the cross headings, and opening up stalls or rooms to work the coal from the pillars, some of which were usually left to prevent subsidence. The stalls were typically ten meters wide and ten meters apart, although they were sometimes opened up to create short-wall faces of 30 meters.

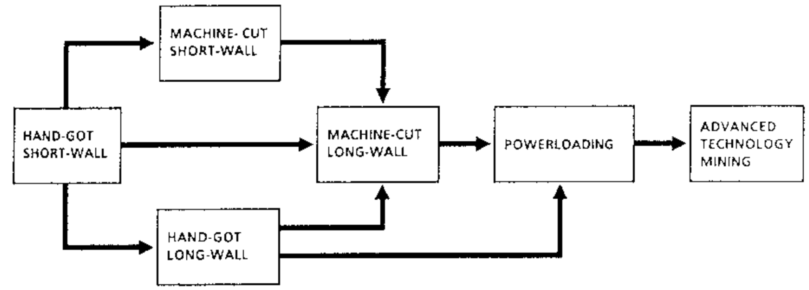

Fig. 1. Phases of the labor process at the coal face (source: Heycock & Winterton, 1989).

Mining involved two operations: coal getting by colliers at the face, and haulage by trammers or putters. The coal was customarily worked by a hewer and his mate: "within these pairbased units was contained the full range of coal-face skills, each collier being an all-round workman, usually able to substitute for his mate" (Trist & Bamforth, 1951, p. 6). First, the hewer undercut the coal with a pick, supporting the face with sprags (props set at an angle to the face). The supports were then removed and the coal was hacked from the face with a pick, broken away using wedges, or blasted down with explosives, depending on the nature of the seam. The loosened coal would then be shovelled by the pair into tubs pushed to the working place by trammers.

Sets of between two and four colliers and trammers worked together, building stone packs to support the gob (the waste area previously worked) when they had advanced an agreed distance. Each miner needed to possess all face skills and the division of labor was minimal: trammers would normally become colliers when opportunities arose to move to the face. Work proceeded continuously, but variations in seam conditions prevented any fixed time schedule for the cycle of operations so each shift continued where the previous shift had left off.

There was no division of labor between miner and machine under HGSW so the manual skills required were extensive. In addition to being able to wield a pick in a confined space, colliers also needed to possess mental skills in order to work the coal safely, whether in South Wales (Paynter, 1972, p. 21) or Pennsylvania (Brophy, 1964, p. 63). Opportunities for supervision were limited by the remoteness of working places, but British miners also rejected the supervision of the overman (Goodrich, 1920, pp. 137-138), and their American counterparts maintained this freedom through collective action (Goodrich, 1925). Dix (1979, p. 163) characterizes the early American miner as "an independent craftsman who worked largely without supervision."

It would be an exaggeration, however, to romanticize the arduous, dangerous work under HGSW as representing craft control. Miners were undoubtedly skilled and enjoyed considerable control over the labor process, but this was not necessarily replicated in the labor market, where the "independent colliers" of one district coexisted alongside the "degraded slaves" of another (Harrison, 1978). The detailed, tacit knowledge of miners at work in their respective rooms was, moreover, less holistic than the knowledge of mine managers. Unlike their counterparts in other industries, mine managers were required by statute to hold a certificate in mining engineering, and were familiar with conditions in all the seams worked by a colliery. It was the relative *invisibility* of miners, rather than the mysteries of the craft, which maintained their job control.

In place of direct control, managers introduced indirect control in the form of payment by results. Colliers were paid according to the tonnage of coal filled, and contracts usually stipulated that deductions would be made for dirt or slack (fine coal, unsuitable for burning under primitive technologies). Other work was either incorporated in the contract or paid for explicitly in the form of supplementary allowances. Miners argued that they had the right to determine their own pace of work because they were only paid for what they did. In place of external supervision, "leadership and 'supervision' were internal to the group, which had a quality of *responsible autonomy*" (Trist & Bamforth, 1951, p. 6).

In studying the Durham colliers, Trist and colleagues concluded that the work group's capacity for self-regulation was a function of the wholeness of their work task. Group cohesion was reinforced by the system of "cavilling," whereby "marrow" (or marra) groups were formed on the basis of mutual self-selection and all members shared a common paynote (Trist et al., 1963, p. 33). However, this practice was not widespread outside of the Durham coalfield (Douglass, 1977, pp. 221-246; Krieger, 1983, pp. 80-90) and even within the North East there is evidence of the divisiveness of payment by results. Williamson (1982) clearly depicts the antagonistic

relations in the exploitation of trammers and the more peripheral pony boys by the colliers in Northumberland. Similar evidence is found in Lancashire (Forman, 1979) and South Yorkshire (Heycock, 1986). Moreover, variations in the method of payment influenced the forms and levels of internal and external supervision. The wholeness of the miners' tasks depended upon methods of work and how miners' skills were employed, and these exhibited significant spatial variation under HGSW. Work organization was affected by the Price Lists, drawn up between the union and the management, whose power over the whole process of production was brought to bear in negotiation. Since different seams in the same colliery had separate Price Lists, the miners were inhibited in generalizing issues to challenge piecework prices or methods of work beyond a particular seam.

While the wholeness of the work task provided the primary work group with a *capacity* for self-regulation, the payment system *necessitated* this response. The relative invisibility of the miners' work, which prompted management to use payment by results to combat the physical difficulties of supervision, further facilitated responsible autonomy. Cohesion was not reinforced by payment by results, but by the miners' resistance to such indirect control.

MACHINE-CUT SHORT-WALL MINING (MCSW)

A primitive coal-cutting machine was developed around 1780 and within a century several different models were available (Taylor, 1961, p. 58). Disc cutters, consisting of a horizontally-rotating disc with teeth along its edge, were difficult to maneuver in short-wall working places. The bar cutter, with teeth ranged along the length of a rotating bar, was also cumbersome. Percussion cutters operated more like a pneumatic drill and were the most maneuverable. The introduction of such machines to existing faces, usually termed machine holing, proceeded very slowly and was never widespread in Britain. By 1913, as coal production was approaching its peak, only 8% of coal was machine cut in Britain (Reid, 1945, p. 4).

Miners were occasionally hostile to the introduction of coal-cutting machines (Taylor, 1961, p. 59), in Nottinghamshire even to the point of striking during the first decade of the twentieth century (Griffin, 1955, pp. 150, 198). The more protracted stoppages, however, concerned payment for machine-holed coal (ibid. p. 158), not the new technology *per se*. Rather than the miners' resistance, a more important factor was the employers' reluctance to adopt machine mining (Griffin, 1955, p. 177; Taylor, 1961, p. 63). The major technical problem was in handling machines in confined working places since they had to be constantly moved to cut a short face of coal. A related social factor was the high skill requirement of mechanized pillar and stall working, which the employers regarded as a disadvantage (Reid, 1945, p. 40). The major economic problem was that capital costs per ton of output were high because each working place needed its own machine. Such capital expenditure was impossible for the proliferation of small collieries operating beyond their peak efficiency and unwarranted given the abundance of cheap labor which sustained them.

While MCSW mining was relatively unimportant in Britain, it was the predominant form of mining in the very thick, shallow seams of America, where it still accounted for 96% of underground production in 1975. At that time, approximately 32% of underground coal was produced by conventional MCSW mining, which entails undercutting the coal by machine, drilling the face and shooting the coal down with explosives. The loosened coal was originally hand-filled but by 1950 loading machines handled 70% of the coal (Yarrow, 1979, p. 171). The remaining 64% of MCSW coal in 1975 was produced using continuous miners. The continuous miner, widely adopted in the 1950s and 1960s, combines the cutting and loading operations in one machine. Compared with conventional MCSW, the continuous miner produces 20–40% more coal with a crew of eight in place of 12, yet the machine is typically working for only 1 hour in an 8-hour shift: "As the time and motion studies indicate, there are ample opportunities for the operator to slow down or speed up coal production by creating delays or avoiding them" (Yarrow, 1979, p. 180).

Because the miners control the speed and direction of machines under MCSW, their collective strength enables them to enlarge discretion in the labor process, determining the pace of work, timing of breaks, and local production decisions. Yarrow (1979, p. 185) regards such discretion as skill and argues that while skill is "a crucial resource for gaining power over the work process," such power also "increases the skill content of their jobs by allowing them to make more decisions." Yarrow appears to confuse autonomy, the control workers maintain over the labor process, with skill, "any combination of mental and manual qualities which it takes time to acquire" (Renold, 1928). Clearly skill and autonomy are mutually supportive, but the undercutting of coal was regarded as the most skilled task under HGSW and the introduction of coal cutters diminished the manual skills involved (Dix, 1979, p. 164). Nevertheless, the cuttermen still needed to understand how best to work a particular seam, so mental skills will have been maintained, if not increased, in the move to MCSW. As with HGSW, however, autonomy was fostered not only by skill but also by the relative invisibility of miners in short-wall working places and the solidaristic character of the primary work group.

HAND-GOT LONGWALL MINING (HGLW)

Geological considerations dictated the adoption of longwall mining in Britain because as deeper seams were accessed, pressure from the overlying strata intensified, making it impossible to work a short-wall face. The longwall technique was widespread in Britain before mechanized mining, and therefore while longwall facilitated mechanization, it was not caused by the adoption of new machinery, as Trist and Bamforth (1951, p. 9) suggested. The deepest mines employed longwall techniques from the outset without any change in the material technical base or even work organization. However, the advantages of the longwall technique for management soon became apparent, prompting changes in work organization affecting first autonomy and later skills, and leading to changes in the material technical base. These "advantages" to management were largely synonymous with the social shortcomings of (mechanized) longwall mining identified by Trist and Bamforth 50 years later.

In the earliest HGLW, coal was removed from a face up to 200 m long by separate sets of colliers, each working their individual places along the face. Even where the technique of production remained otherwise the same as under HGSW, the altered physical layout made the miners' work more visible to management and opened it up to greater supervision. The problem for management under short-wall mining was how to control the work of miners in many separate workplaces hundreds of meters underground and perhaps many kilometers from the pit bottom. In HGLW the miners were still in separate work groups but in one workplace which was more accessible to management. The advent of longwall mining effectively removed the walls of the colliers' rooms, in much the same way as office work is changed by the open-plan configuration. Conditions became more uniform along the longwall face, allowing managers to transfer colliers between workplaces more easily. However, colliers also found it easier to make comparisons among themselves along a face, between different faces and seams within a colliery and between different pits working the same seam.

The colliers were more easily supervised under HGLW but their skills were intact and inroads into their autonomy were limited so long as they retained discretion over task elements. The second change in work organization under HGLW entailed a new division of labor in which miners were divided into holers, who undercut the coal and were the most skilled, getters, who broke into the coal and got it down, and fillers, who loaded the coal into tubs. Contemporary mining manuals confirm that management were well aware of the advantages conferred by division of labor at the coal face. In an echo of Adam Smith's famous declaration, one manual noted how miners become "proficient in their respective classes of work and therefore do it well and cheaply" (Peel, 1893, p. 129). Another noted there is "easier supervision of workmen and a greater number of men can be set to work in a given length of face than in bord and pillar stalls" (Bailes, 1906, p. 28). The division of labor reduced the breadth of each individual's skill, thereby eroding job autonomy and facilitating more close direction and supervision of work.

Compared with short-wall mining, HGLW produced coal faster, cheaper, and of a better size. A mine became profitable more quickly and less coal was left wasted. Roads (main tunnels) were generally shorter, straighter, and more direct, but as the gob became more compressed over time, more packing (wood and stone supports built at each end of the face) and ripping (removing rock to maintain the height of the main gate and tail gate, the headings providing access to the face) was necessary, contributing a higher proportion of labor costs than in HGSW. If the coal was not worked for any length of time, the strata above would exert pressure on the face, but if the coal was mined continuously there was an "uplift" in the seam which made successive coal-getting from the face easier. Shift working, introduced to gain the geological advantages of continuous mining, was easier under longwall mining because working conditions were more uniform, enabling more than one set of miners to work in the same place.

Even before mechanization, therefore, longwall mining influenced three major developments in coal-face work: increased supervision, division of labor, and the introduction of shift work. Compared with short-wall mining, HGLW represented a spatial concentration and temporal intensification of work at the coal face. The intensification of face work made haulage improvements necessary so that the rate of production was not held up "outbye" (away from the coal face), while its spatial concentration made such improvements possible. Conveyors were seldom used in short-wall working in Britain because of the impracticality of running a conveyor into every room. The use of this "common factory device" in American short-wall mining between the wars necessitated changes in mine layout (Goodrich, 1925, pp. 131-132). With HGLW in Britain the apparently small change in the material technical base which the use of conveyors on the face represented, had a dramatic effect in association with other innovations in work organization and proved the key to effective face mechanization.

MACHINE-CUT LONGWALL MINING (MCLW)

Mechanized longwall mining entailed a material technical base of coal cutting machines and face conveyors, which had been employed in earlier forms. In some cases, MCLW emerged as a logical extension of HGLW, where conveyors and division of labor had been introduced. Under MCLW, however, work organization was far more rigid and based on a more extreme division of labor. Face work was divided into small elements and a cycle of five operations was spread over three shifts. On the preparation shift cuttermen used coal cutters to make an undercut at floor level along the entire length of the face. The undercut, or gummings was cleared out by gummers so that the coal would fall from the face when fired. At intervals along the face, borers drilled holes into which explosives were placed. At the end of the preparation shift or the start of the coaling shift, the coal was shot off the face by shotfirers, then the loosened coal was filled onto the conveyor. The fillers were required to shovel however much coal had been loosened, otherwise work was held up on the following shift. On the repair shift the conveyor was dismantled, moved forward as far as the face had advanced, and re-assembled by conveyormen. Packers built stone packs to absorb the shock and protect the headings when the roof was collapsed. Packers also set new props to provide a working area for the next preparation shift before removing the old supports to collapse the previous working area into the gob. Rippers removed rock from the roof where the gates joined the face in order to maintain the height of the headings.

Machine mining was more suited to the longwall technique because the coal cutters remained on the face and were more heavily utilized, so represented lower capital costs per ton than under MCSW. Larger, more powerful chainsaw machines were also developed for the longer runs of coal cutting under MCLW. Nevertheless, even with the widespread move to longwall mining in Britain, mechanization proceeded slowly. The major impediment to modernization of the coal industry was its economic structure, which was marked by a large number of small, labor-intensive collieries (Samuel, 1926). The mine owners responded to unstable market conditions for coal by varying wages, working hours, or the numbers employed. Under such conditions coal owners would not invest in mechanization when successful in keeping the price of labor low. Mining journals and manuals advised managers to introduce coal cutters into longwall mining only if coal could be produced more cheaply than with hand-got methods (Boulton, 1907; Kerr, 1921).

There was considerable variation in the rate of mechanization of the major coalfields; coal cutters were used to access thin seams in Scotland (Taylor, 1961, p. 60), but were seldom employed in the faulted coal of South Wales (Reid, 1945, p. 11). Despite the labor shortages and fuel demands of the First World War, and Acts of 1908 and 1919 limiting the length of the working day, by 1925 only 20% of output came from mechanized faces. The miners' defeat in the 1926 lockout and the passage of the

1926 Act allowed coal owners to continue primitive forms of production based on the pursuit of absolute surplus value (Fine, O'Donnell & Prevezer, 1982, p. 33) . However, when the 1931 Act restricted hours, employers were induced to introduce new methods to raise relative surplus value, and by 1938, mechanized faces were producing 59% of British coal (Page Arnot, 1953, p. 528).

The increase in mechanized output in Britain between the wars was due less to introducing additional cutting machines than to intensifying the use of existing machines, principally through employing more conveyors. The significance of conveyors is demonstrated by the lesser impact of coal cutters in MCSW, where conveyors were not employed, than in MCLW. The number of face conveyors increased from 2078 in 1927 to 5859 in 1939 (Reid, 1945, p. 6), while the total number of conveyors increased from 2185 in 1927 to 7826 in 1938 (Page Arnot, 1953, p. 528). Therefore, while there was a threefold increase in face conveyors, the number of tail-gate conveyors increased by a factor of 18. Tail-gate conveyors allowed more coal to be cleared from the face, making it possible to intensify face work, "speeding up" as Page Arnot (1953, p. 528) described it.

The social impact of MCLW mining was detrimental to miners, who found their work intensified, deskilled, and dehumanized. Ebby Edwards, President of the Miners' Federation of Great Britain, complained to the 1931 Conference:

> It is not a process adapted to meet the human needs of the workers . . . . Under a sane system of society, rationalisation should reduce the working time and give improved standards to the workers. Instead of this, you rationalise and produce unemployment, and the reduced number work with increased intensity (Page Arnot, 1961, p. 60).

Under MCLW methods, the miner "was still involved in considerable effort with little scope for the exercise of the skill he had acquired through the old system" (Reid, 1945, p. 6). Tasks were divided between the worker and the machine:

> . . .the machine eliminated the most skilled part of the work, namely, the holing or undercutting of the coal, thus making it possible for unskilled men to enter the mine freely and in a short time to take their place alongside the skilled collier . . . the skilled man had forfeited his skill and "pit sense" and if he had not the physical strength of the unskilled man he could not possibly make the same wage (Stewart, 1935, pp. 35-36).

The division of labor was so extreme that one class of worker seldom substituted for another on the same shift, and work left from one shift was not completed by the next. Tasks became more specialized and none required more than a fraction of the old hewer's skills. The Tavistock researchers found only 19% of the available skills were used on conventional mechanized longwall faces and that other skills could only be used by special arrangement (Trist et al., 1963, p. 247).

The miners' work had been dehumanized, disturbing the "social balance" which had existed under HGSW. This social disruption was the result of attempting to introduce mass production techniques to the coal face:

> Differentiated, rigidly sequenced work systems, organized on mass production lines to deal with large quantities of material on a multi-shift cycle, are a basic feature of the factory pattern. Even in the factory situation, their maintenance at a level which allows full and continuous realization of their technological potentialities creates a difficult problem of industrial management. In the underground situation these difficulties are of a higher order, it being virtually impossible to establish the kind of constant background to the task that is taken for granted in the factory. A very large variety of unfavorable and changing environmental conditions is encountered at the coal-face, many of which are impossible to predict. Others, though predictable, are impossible to alter (Trist & Bamforth, 1951, pp. 19-20).

The social effects of MCLW mining became manifest in a variety of ways. The most visible impact was on the accident rate, particularly from roof falls, because machine vibration increased the risk of a cave-in, while the dust and noise obscured the sight and sound of impending danger (Stewart, 1935, pp. 45-46). Increased dust also created respiratory problems. Rock dust was known to cause silicosis, but coal dust pneumoconiosis was only later identified as a distinct, and more widespread, disease, which HM Inspectorate of Mines linked to mechanization (Meikeljohn, 1952). In Scotland, where 60% of coal came from mechanized faces by 1928, there was a four-fold increase among underground workers in nystagmus, an eye disease attributed to poor luminosity and stress (Wilson, 1945, p. 41). Trist and Bamforth (1951, pp. 4-5) referred to the work of Dickson (1936) and Halliday (1948), Scottish general practitioners who discovered an epidemic of stress-related illness among miners. Halliday (1948) found stress-related illness to be prevalent among skilled miners. Moreover, in the period 1930-1932, the death rate of wives of skilled miners was 40% higher than that of wives of other workers; many of the miners' wives died of hypertensive heart disease. Unemployment was clearly associated with ill health in mining communities. In 1932, unemployment among mineworkers reached 42% nationally, while some localities in Scotland, Durham, and South Wales recorded levels of 66%. However, the differential impact upon the households of skilled miners suggests that changes in the labor process were also implicated in the patterns of ill health.

When economic conditions improved, the negative social effects of MCLW mining became apparent in other ways. Even under wartime control, but particularly after nationalization in 1947, absenteeism became endemic to the British coal industry (Liddell, 1954; Handy, 1968). Unofficial strike activity was similarly widespread (Saxena, 1955) even before the repeal in 1951 of wartime order 1305 which had made strikes unlawful. The coaling shift universally saw more disputes than others as fillers bargained allowances from management to compensate for failure to complete the task under adverse conditions (Winterton, 1981, p. 14).

The fillers' work retained the physical effort of the colliers' job under HGSW with few remnants of the skill or autonomy. Scott et al. (1963, p. 181) found morale to be lowest among fillers and packers, in contrast with the craft workers and rippers who still worked in small stable groups. Even on the preparation shift, however, there was social tension between the cuttermen and gummers, who worked separately. The cuttermen were the most skilled and highest status faceworkers, whereas the gummers were the least skilled, lowest status: "hostility in them . . . is almost inevitable and is most easily displaced on the fillers, whom they never see but can severely annoy . . . by leaving in some of the gummings under conditions of fatigue or difficulty" (Trist & Bamforth, 1951, p. 35).

POWER LOADING

The problems associated with MCLW mining demonstrated the need to eliminate hand filling and introduce a system of continuous mining with coaling on all three shifts. The Reid Committee (1945, p. 54) described European power-loading machines, capable of simultaneously cutting and loading coal, as a "revolutionary development in mining techniques." The American continuous miner combined both operations but was unsuited to longwall mining and the geological conditions of British mines.

The technical base of power loading was the shearer, a machine which traversed the coal face, breaking away the coal with a series of picks ranged round a rotating drum, and directing the coal onto a conveyor. The face now advanced continuously on each shift, rather than a fixed distance once over a three-shift cycle. Power loading therefore also required the development of an armored flexible conveyor (AFC), capable of being moved onward with the advance of the face line, without being dismantled. Hydraulic pit props offered more stable roof support in the working environment subject to vibration from power loading machinery, and were ultimately modified to ram over the conveyor. Toward the end of the 1950s, the Anderton Shearer Loader (ASL) was developed with the involvement of working miners; over 50% of the awards for design innovations went to miners, machine operators, fitters, and electricians (Townsend, 1976, p. 11). Although machines like the Meco Moore, Trepanner, Huwood Slicer, and the rapid plough had been utilized to a limited extent (NCB, 1971), the success of power loading was largely due to the application of the ASL in preference to other machines (Kelly, 1969, p. 136).

The technique of mining under power loading differs from MCLW mining in that the operations are continuous. As the shearer traverses the coal face, the conveyor is pushed over toward the face behind the machine and the supports are advanced to the position formerly occupied by the conveyor. In this way, the new face line is established by the time the shearer reaches the gate at the end of the face. The machine is then reversed and the same operations performed to bring the shearer back to the other gate. Rippers develop the headings as the face line moves away from the roadway, and the tail-gate conveyor is lengthened. The same coal-winning techniques are employed in reverse with retreat mining, where the face is established at the extreme end of the panel of coal and worked back toward the roadway. On a retreat face, however, all the development work of the headings is completed before the face is established.

Fine, O'Donnell and Prevezer (1983, p. 16) argue that power loading "did not by itself radically transform conditions of control over the labor process," while Douglass (192, p. 1) notes that power loading led to increased supervision. Technology was a major factor influencing work organization, as Trist and Bamforth argued, but it is important to distinguish the constraints imposed upon work organization by technology from attempts by management to introduce new working arrangements coincident with changes in technology.

In place of the extreme division of labor between shifts, and between groups on the same shift, each shift now performed the same tasks. Although workers were specialized as craftsmen, machine men, rippers, and so on, they were interdependent members of a *team* and regained some of the former social cohesion face workers had experienced under HGSW. Power loading eliminated the skills that remained in undercutting but demanded new skills of faceworkers and craftsmen. Face workers on *every* shift needed manual skills associated with guiding the shearer along the face and knowledge-based skills akin to those of the hewers under hand-getting. More craft workers were needed to install and maintain the power loading machinery; as a proportion of the workforce they increased from 6% in 1957 to 14% in 1970 and 20% in 1981. Fitters and electricians needed specialist skills to diagnose and repair faults with the shearers, conveyors, and hydraulic supports. The reskilling of face work and craft work made management control over the labor process more difficult. Moreover, since the rate of production on one shift was independent of the work of the previous shift, power loading was conducive to workers regaining control over the pace of work and timing of natural breaks.

Power loading therefore facilitated significant changes in work organization. Tasks were reunified, new skills required, and a degree of autonomy was returned to face teams. The NCB attempted to introduce new working arrangements which would restore management control in response to the miners' increased control over the labor process under power loading. Indirect control via piecework was inappropriate because output was no longer dependent upon physical output, and because management wished to avoid the introduction of power loading being disrupted by fragmented bargaining at the coal face.

Between 1948 and 1966 power loading agreements which removed piece work from power-loaded faces were negotiated first on a district basis (Winterton, 1981, pp. 14-15), and then in the National Power Loading Agreement (NPLA) in 1966 (Searle-Barnes, 1969; Handy, 1981). To combat the reskilling associated with power loading, the NCB sought to make workers more interchangeable under the NPLA:

> specific jobs such as those of chockman, ripper, stableholeman and so on disappear and a man becomes . . . a "taskworker." It implies also a merging between craftsmen and the face workers so that the labour force develops into an undifferentiated group (Heath, 1969, p. 187).

The objective of increasing flexibility represented a conscious attempt by the NCB to avoid the disruption of production caused by the division of labor under MCLW mining. Flexibility had a positive spin-off for miners in supporting the reunification of face work. However, flexible labor necessitated more direct instruction by management, effectively separating conception from execution and reducing workers' discretion. Face production plans under the NPLA detailed management responsibility to "check the exact time the men arrive at and leave the face . . . [and] check the actual speed of the machine against the planned speed" (Heath, 1969, p. 189).

Greater emphasis was placed on direct control in an effort to raise actual output closer to the potential output of the machines. Unless management could distinguish between workers restricting output and diverse geological and operational problems, it was impossible even to establish realistic production targets. To increase supervision a higher proportion of underground officials was employed and the NCB (1968) reported that "intensive efforts continued at collieries to extend the running times of power loading machines, particularly by the use of method study techniques and by the appointment of officials at each colliery as delay shooters."

The collapse of coal demand during the cheap oil era and the successful introduction of power loading together eliminated almost half a million jobs, two-thirds of the workforce, between 1957 and 1971. These product and labor market changes reduced the miners' bargaining power, while the power loading agreements removed opportunities to engage in fragmented bargaining over pay, and miners' relative earnings declined substantially (Hughes &

Moore, 1972). Nevertheless, the miners' control over work was evident both in autonomy at the point of production and in the power retained by local NUM branches over pit issues (Edwards & Heerey, 1989, pp. 32-33). With wages no longer dependent upon output, miners were able to use their control over work to restrict output in response to declining relative earnings and increased supervision. In Yorkshire, for example, the achievement of task norms under the NPLA brought earnings only marginally above the Comprehensive Power Loading Agreement fallback rate, so face workers were content to economize on effort in difficult conditions and accept guaranteed earnings (Hepworth et al., 1969). The removal of piece work and elevation of collective bargaining, allied to the miners' weakened bargaining position, led to a substantial decline in strike proneness from 1958, which accelerated after 1966. While the proportion of strikes over pay issues fell, working arrangements, particularly manning levels, became a focus of conflict (Winterton, 1981, p. 15). This change in strike issues reflected both management attempts to reduce task discretion while intensifying the pace of work and the miners' willingness to defend their control over the labor process.

When the Third Daywage Structure Agreement of 1971 completed the move toward industry-wide pay bargaining, the miners' union became more unified behind national wage claims (Rutledge, 1977), and a militant rank-and-file movement brought to power left-wing leaders committed to arresting the decline of miners' earnings (Allen, 1981). The success of the 1972 strike, the first national stoppage since 1926, followed by the 1973 oil shock, restored some of the miners' bargaining power. Moreover, management had expressed dissatisfaction with the stagnation of productivity growth in the 1970s, although there was no justification for anticipating further increases in productivity without further change in the material technical base once power loading had been comprehensively introduced. In response to the altered economic and political context, NCB management considered ways of fragmenting pay bargaining, reducing the influence of the emergent left leadership of the NUM, and limiting miners' control at the point of production in the design of new technologies (Winterton & Winterton, 1989, pp. 9-12). These strategies had a profound influence upon the implementation of *Plan for Coal,* the corporatist settlement of the 1974 strike which consolidated the miners' gains in a tripartite agreement to expand coal production by investment in new mines and new technologies.

ADVANCED TECHNOLOGY MINING (ATM)

The most recent phase of coal-face work represents a refinement of the material technical base of power loading with the use of computer automation and more powerful face machinery. To identify ways of increasing productivity in line with the objectives of *Plan for Coal,* the Operational Research Executive of the NCB reviewed colliery activities using systems engineering. The exercise demonstrated that major gains would be made from automation and coordination of separate functions rather than from specific mechanical innovation. This change of emphasis is reflected in the Mining Research and Development Establishment (MRDE) expenditure pattern between 1975 and 1982; while research on coal-face projects fell from 30% to 15% of total expenditure, research on computer-based comprehensive monitoring increased from 10% to 25% of total expenditure (Jones et al., 1984, pp. 65-69).

Systems analysts broke down colliery activities into distinct but related logical subsystems, and functional systems with objectives that computer scientists and engineers could develop operational systems to meet. Thus, coal face activities were broken down into delay monitoring (causes of stoppages), condition monitoring (reliability of coal-face machinery), automated shearer guidance (in both vertical and horizontal planes) and face advance (automatic advance of roof supports and conveyor). Separate operational systems were developed for each, except that vertical guidance and condition monitoring were combined in a single system. The MINOS package developed out of this program is shown schematically in Fig. 2. The technical characteristics of MINOS have been analyzed extensively elsewhere (Burns et al., 1982, 1983, 1984b, 1985; Winterton, 1985), and a brief description of certain features will suffice for present purposes.

The various MINOS subsystems, devoted to machine monitoring, coal clearance, environmental monitoring and so on, are controlled by a primary computer which reports to staff in a surface control room. From the control console, conveyors are automatically started or stopped and bunkers loaded or discharged, the sequence of operations having been predetermined and programed into the system software. Mimic displays of the coal face, conveyor systems and other operations are presented on VDUs and when face machinery, fans or pumps are not working, control room staff are alerted. The separate MINOS subsystems are designed to interface and interact, providing in the colliery control room a continuous picture of operations and information for longer-term analysis by a secondary computer dedicated to a management information system.

A key system objective was to raise productivity by increasing machine available time and machine running time. Work measurement in the early 1970s had revealed that the average shift at the coal face was divided approximately equally into coal cutting, operational delays such as breakdowns, and delays caused by face workers taking natural breaks. Operational delays were to be reduced by automated monitoring which would identify abnormal conditions indicative of actual or imminent failure, allowing corrective action to be taken more quickly. The subsystem MIDAS (Machine Information Display and Automation System) employs transducers and a microprocessor on the shearer to monitor oil pressure and temperature continuously, while regular manual measurements from other machines are analyzed using the IMPACT (In-built Machine Performance and Condition Testing) program to predict breakdowns. The aim is to make preventive maintenance condition-based rather than time-based, allowing repairs to be scheduled outside production time, before failure. Such monitoring and analysis also improves the reliability of ancillary machinery, reducing down-time due to failures of fans and pumps.

To reduce man-made delays, the NCB reintroduced incentive payments and developed computerized surveillance of face work. The subsystem FIDO (Face Information Digested On-line) enables control room staff to identify the position of the shearer, whether it is cutting coal, and the nature and duration of all delays. Delays of less than 20 minutes adversely affect bonus earnings, whereas a contingency rate is paid for

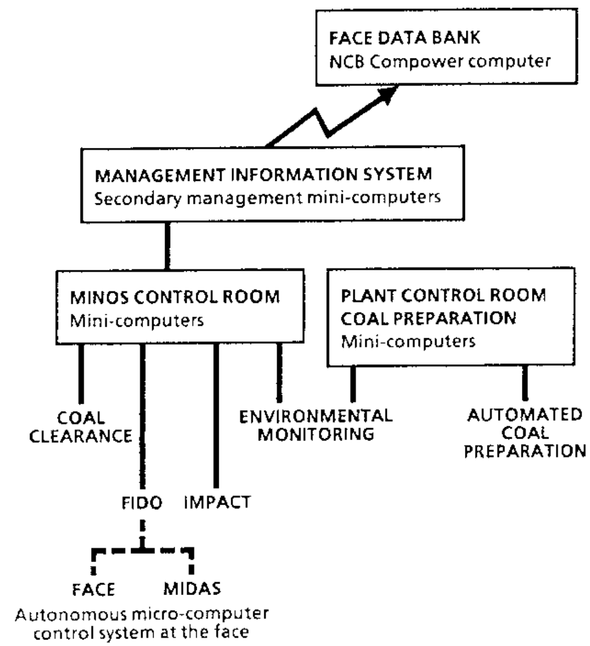

Fig. 2. The MINOS hierarchy (source: Burns et al., 1983).

genuine operational delays lasting at least 20 minutes, so miners are penalized for unscheduled breaks.

In addition to increasing machine running time at the coal face, by reducing operational delays and unscheduled breaks, MINOS facilities intensify the rate of production in other ways. The automated steering function of MIDAS increases the rate of extraction, often doubling face output because the machine driver no longer has to concentrate on preventing the machine from cutting the roof or floor. Automation and coordination of belts and bunkers has significantly removed haulage bottlenecks, and the availability of coal clearance to the face is now only exceptionally below 90% of production time.

The potential of MINOS to keep the coal face operating continuously at a high rate of extraction demanded more robust face machinery. Heavy duty face equipment (HDFE) was therefore developed, comprising a more powerful shearer-loader, banks of self-advancing roof supports with face shields, and heavy duty conveyors. Gate-end electrical equipment is similarly up-rated to convey sufficient power to the coal face. The development of HDFE represents a refinement of the material technical base rather than a fundamental change, but is nevertheless necessary to achieve the productivity potential of computer monitoring and control. Advanced Technology Mining (ATM) refers to the marriage of HDFE with MIDAS automated steering, a combination capable of producing a daily face output of 4000 tons with two men on the face line. According to the former head of MRDE, the parallel application of HDFE and microelectronic control systems brought a "huge reduction in downtime due to machine failure" (Tregelles, 1986). The demands imposed on development work by such a dramatic increase in the pace of production also led to a change in the technique of production, from longwall advancing to retreat faces, both standard longwall and short-wall "single-entry" faces which have only one gate as a means of access or egress.

ATM and its component parts have altered the nature of work throughout British coal mining. Two design features of MINOS are particularly significant and betray managerial objectives made explicit in the technical literature by the scientists and engineers involved. In the first place, direct closed-loop computer control predominates, reducing human decision-making and thereby the skills required of operators. Second, the system is hierarchical and centralized, designed to reduce miners' job autonomy and increase management control. These characteristics are not simply the inevitable consequence of technological developments to raise productivity but, rather, reveal a Taylorist approach to work organization. The design strategy adopted by operational research analysts, computer scientists, and engineers is a stark contrast to the conclusions of Trist and

Bamforth, who stressed the importance of restoring autonomy to work groups and promoting flexibility in the pace of work.

Some skills of face work have been eroded by ATM because with automatic computer guidance of the shearer, the face worker no longer has to steer the machine: the machine driver's skills have been embodied in the guidance system. The number of workers in a face team has declined from an average of 16 (up to seven in the gates and up to 12 on the face itself) to half that number, in some cases with only one or two miners on the face line during a production shift. As the size of face teams has been reduced, the range of tasks assigned to individual workers has increased. Face workers have been given responsibility for various ancillary tasks but this does not represent "reskilling" because the additional tasks are generally of an unskilled nature.

The job enlargement of face workers is mirrored in the reorganization of work of deputies and craft workers whose physical areas of responsibility have been extended. The deputies' duties have been redefined with more emphasis on supervision, although even with automated environmental monitoring they have so far retained statutory safety responsibilities. Craft work has been affected by computer-based machine monitoring which incorporates diagnostic skills in the system software.

Routine Condition Monitoring (RCM) has involved both a reduction in the number of craft workers, and profound changes in the organization of their work. Craft work has been "routinized," insofar as tasks are predetermined by management and there is less opportunity to exercise discretion. Fitters and electricians have been merged into "multi-skilled" electro-mechanics who undertake the replacement of faulty modules rather than fault-finding and repair. This reorganization of craft work, explicitly described as deskilling by management, has also intensified work by reducing the porosity of the working day. Fewer shifts are now spent on maintenance, further increasing productive time. Surplus craftsmen have been redeployed as machine drivers because management aims to encourage them to undertake nuisance breakdown repairs. The degree of craft-production flexibility is, however, limited compared with the multiskilling of craft workers and increasing interchangeability of face workers.

These changes in the organization of craft work contradict predictions that the new technology would entail "increasing numbers of maintenance workers with enhanced skills" (Penn & Simpson, 1986, p. 348). The claim that new technology had reskilled craft work (Simpson & Penn, 1987) was based on research in two Lancashire pits, neither of which had MIDAS, IMPACT, or RCM, the very changes which have deskilled maintenance tasks. The only evidence of reskilling is the emergence of technician craft workers who maintain the computer systems, and these are invariably contractors from the companies supplying the equipment rather than British Coal employees.

The reduced autonomy of craft workers derives both from the deskilling effects of new technology and changes in work organization, especially the introduction of RCM. At the coal face, autonomy has been reduced through computerized work monitoring, increased supervision, and changes in work organization. The FIDO surveillance system, dubbed the "watchdog" by miners, operates like a tacograph, reporting delays to the surface control room and recording performance for analysis by a Management Information System. The greater visibility of coal-face work to management on the surface is a key factor in the loss of autonomy at the face. Increased supervision has been facilitated by changes in the role of deputies and is supported by computerized monitoring which supplies an incontrovertible record. Both forms of external supervision provide means of adjusting the effort–reward bargain in management's favor through modifications to the incentive scheme, which effectively internalizes supervision. With detailed knowledge of peak work rates and delays, management can increase task norms and miners must work at greater intensity or accept lower earnings. A significant change in work organization in the North East has been the replacement of cavilling traditions by managerial prerogative in the allocation of tasks and overtime, and in the selection of members of face teams (Tomaney & Winterton, 1990). Trist and Bamforth placed great emphasis on the cohesiveness of self-selected work groups, and the end of cavilling can be seen as an attempt to modify the solidaristic character of face teams.

The new technologies were developed, tested, and quite extensively installed prior to 1984 without significant changes in work organization, demonstrating the scope for choice in work organization argued by Trist and Bamforth. It was the defeat of the 1984-1985 miners' strike which provided a permissive environment in which management could unilaterally restructure work organization and reconstruct industrial relations in order to extract the maximum return from ATM (Leman & Winterton, 1991). The privatization of electricity supply, and the prospect of privatizing coal, intensified pressures on management to adopt new commercial perspectives along with the new corporate name, British Coal. Stringent cost objectives were established in the Moses Strategy in 1985 (Winterton, 1990) while the means of attaining these, including controversial temporal flexibility, were outlined in the Wheeler Plan (Winterton, 1991b).

Since the development of ATM, productivity has increased by 161%, from 2.43 tons per manshift in the year ended March 1984, to 6.35 tons per manshift mid-way through the year to March 1993. This dramatic improvement was the combined result of three main factors. First, the closure of less productive capacity and the expansion of output from modern complexes like Selby raised the industry's average performance. Between March 1984 and September 1992, 70% of collieries closed whereas output fell by only 22% (Winterton & Winterton, 1992). Second, the diffusion of new technologies both increased the rate of production and reduced labor requirements through automation. When disaggregated to colliery level, the growth of productivity conforms very closely to the pattern of investment in new technology (Winterton, 1988). Third, work intensification has been accomplished through a combination of computerized work surveillance, external supervision, and internalized supervision in the form of modified incentive schemes. The intensification has been as apparent in the North East, where there has been little investment in new technology, as in the high-technology Selby complex (Tomaney & Winterton, 1990). All of these changes were underpinned by industrial relations restructuring which reinforced and made permanent the altered balance of power following the defeat of the 1984-1985 strike (Leman & Winterton, 1991).

The use of ATM is confined to predictable mining conditions mostly found in the central coalfield of Yorkshire and the Midlands, largely because the new technologies have been designed without worker involvement and in order to reduce workers' skills and autonomy. A machine driver in Durham commented that MIDAS could only be used where "an idiot" could keep the shearer in the seam. The design philosophy of MINOS is inadequate from the perspective of the coal-face worker, whose skills are more versatile and adaptable to difficult mining conditions. Taylorist design strategies stifle human ingenuity by reducing the scope for workers to exercise real skills and accept responsibility in return for autonomy. As Trist and Bamforth argued in relation to task specialization, Taylorist work organization is not necessary for industrial efficiency and can prove counterproductive due to its negative social effects. These effects are becoming evident once again as work intensification, deskilling, and reductions in the size of face teams have destroyed the social balance at the coal face.

Despite dramatic productivity levels, now in excess of 12 tons per manshift, the world's most technologically-advanced mine complex at Selby has experienced continual problems of random breakdowns. In response, management established teams of Analytical Trouble Shooters, comprising miners, craftsmen, and chargehands, explicitly seeking to harness the skills and expertise of the work force which the computer systems have been designed to circumvent. The Kepner Tregoe consultants who introduced this quality circle program have made little progress because the low-trust dynamic of Taylorist work organization has been exacerbated by poor industrial relations and low morale since the 1984-1985 strike (Winterton, 1991a). The trouble-shooter philosophy has collided with prevailing views among the work force that production delays are management's problem and that task demarcations preserve jobs. Random delays and breakdowns are welcomed as a break from the intensified pace of work and for the opportunities they provide to earn overtime when undertaking repairs. Such attitudes are perfectly rational when technology is designed according to Taylorist principles and management is attempting to foster responsibility for reducing delays without promoting autonomy. The social cohesion which remains within face teams is mobilized to resist management objectives rather than to support them. Had technology and work organization been developed to support workers' creative skills, foster responsible autonomy, and build upon the solidaristic nature of the primary work group, the quality circle program might have enjoyed more success or even have been unnecessary.

CONCLUSIONS

The above review of technological developments at the coal face demonstrates both the complex interrelationship between the dimensions of technology and work organization, and the impact of the wider context of the labor process, especially in relation to the balance of power between labor and management.

In the HGSW era, colliers enjoyed considerable autonomy and control over their work, largely as a result of the inaccessibility of working places rather than the possession of skills or knowledge above a level of which management was aware. Management attempted to combat the miners' autonomy and control labor indirectly through the use of payment by results. Coal-cutting machinery was rarely introduced to short-wall faces because machine utilization was too low to give an adequate return on investment. Where MCSW existed, the material technical base was altered, and the technique of production changed, but the change to work organization was minimal and miners retained much of the (contested) control which they had enjoyed under HGSW.

The move to longwall mining in response to the geological conditions of deeper seams was more significant than the introduction of early coal face machinery. The material technical base of HGLW was the same as that of HGSW, and techniques of production differed little, but work organization was restructured. Direct supervision became feasible and the greater accessibility of the working places to management enabled the miners' control over the labor process to be weakened. The miners' autonomy was reduced even where they continued to exercise much the same skills at the face.

The move to longwall mining greatly facilitated mechanization because coal cutters could be used more efficiently than was possible with MCSW. With MCLW, the changes in the material technical base and technique of production were significant but the changes in work organization had the greatest impact upon face workers. The miners' weakened bargaining position following the 1926 defeat and the depressed state of the industry between the wars, enabled the employers to intensify work and impose new forms of work organization to the detriment of miners' health.

After nationalization, coal was needed to fuel postwar reconstruction, the miners' bargaining power was restored and they reacted to the work situation with absenteeism and unofficial stoppages. It was in this altered context of coal demand outstripping supply and apparently intractable labor relations problems, that the NCB considered alternative forms of work organization to alleviate the social dislocations of the MCLW "three shifts" system. The Tavistock researchers were therefore afforded a unique opportunity of undertaking action research to develop a more human-centered organization of work at the coal face.

Experimental forms of work organization derived from the single place tradition were described as "composite longwall working" and made the whole of the shift team's skills available. Composite work groups were shown to experience greater job satisfaction and better social health, as well as being more productive. Trist (1989, pp. 254-255) acknowledged that "a major factor in this success was that the component groups, which were self-selected, had previously worked together on 'short-walls'." Recent experience of short-wall working was virtually unique to the Durham coalfield, making it difficult to generalize to other coalfields which had adopted longwall working much earlier. The effectiveness of composite longwall working was never extensively assessed in other areas because MCLW mining was overtaken by power loading which transformed face work and made the experiments appear irrelevant. While the substantive recommendations of Trist and colleagues became redundant, the principles they identified are relevant to subsequent technological changes.

The new material technical base of power loading brought associated changes in the technique of production and work organization which restored some of the miners' control over the pace of work. As the industry moved from under-capacity to demand-deficiency, and the miners' bargaining power was reduced, management sought further ways of exerting control through increasing coal-face supervision. Nevertheless, attempts to increase productivity through direct supervision met with difficulties under the day-wage system and miners retained much of their control at the point of production.

The first oil shock in 1973 restored the miners' power in the labor market, reinforcing their control over the labor process. The incentive schemes introduced in 1977 with the aim of re-establishing indirect supervision were tailored to computer-based work monitoring developed as part of the automation program. Face equipment is more robust under ATM but otherwise the material technical base and technique of production are not fundamentally different from power loading. Changes in work organization, however, stem from the strategies of control developed by management since the late 1970s but only implemented in the aftermath of the miners' defeat in 1984-1985.

The development of ATM could be described as a textbook example of the use of systems engineering but in defining the system, the human interface has been inappropriately specified. Human factors were only considered in a Taylorist sense of designing new technology to reduce dependence on workers' skills and increase management control. Wider sociotechnic considerations were ignored, yet from the Tavistock experiments, the negative social effects of work intensification and deskilling could have been predicted. These negative social effects, manifest in low morale and continued production delays, are the result of using technology as a weapon against the workforce. Even at the time of writing the human factors assessment of the new technologies by British Coal has not extended beyond an ergonomic study of control room operations.

The approach adopted by the NCB in the development of ATM has precluded the involvement of miners either in exploring different forms of work organization, along the lines of the Tavistock experiments, or in refining the new technology, as they did when power loading was introduced. The lack of union involvement was not due to weak organization, since more new developments were introduced to the militant Yorkshire collieries than to the more accommodative pits across the border in Nottinghamshire. The NUM was slow to respond to the new technology because of its piecemeal introduction, and when the union attempted to negotiate involvement, management refused to discuss a new technology agreement (Winterton, 1985). Management's approach provides support for Child's (1985) view that enterprises dominated by professional engineers will use new technology to reduce dependency on skilled labor. However, mining engineers always dominated the NCB, but only chose to exclude the miners in the latest phase of technological development, probably in response to the industry-wide strikes of the 1970s and the emergence of a militant leadership of the NUM. It is ironic that sociotechnic action research has ultimately had so little influence in the industry which provided the setting for one of its most widely-acclaimed examples.

REFERENCES

ALLEN, V. L. *The militancy of British miners.* Shipley: The Moor Press, 1981.

BAILES, C. M. (Ed.). *Modern mining practice: A practical work of reference in mining engineering.* Sheffield: Bennett, 1906.

BLAUNER, R. *Alienation and freedom: The factory worker and his industry.* Chicago: University of Chicago Press, 1964.

BOULTON, W. S. *Practical coal mining.* London: Graham, 1907.

BRAVERMAN, H. *Labor and monopoly capital: The degradation of work in the twentieth century.* New York: Monthly Review Press, 1974.

BROPHY, J. *A miner's life.* Madison: University of Wisconsin Press, 1964.

BROWN, R. K. Research and consultancy in industrial enterprises. *Sociology,* 1967, *1,* 30-60.

BURNS, A., FEICKERT, D., NEWBY, M., & WINTERTON, J. *An interim assessment of MINOS.* Report No. 4, Working Environment Research Group, University of Bradford, 1982.

BURNS, A., FEICKERT, D., NEWBY, M., & WINTERTON, J. The miners and new technology. *Industrial Relations Journal,* 1983, *14*(4), 7-20.

BURNS, A., NEWBY, M., & WINTERTON, J. The Restructuring of Work in the British Coal Mining Industry. British Sociological Association Conference, University of Bradford, 2–5 April 1984. (a)

BURNS, A., NEWBY, M., & WINTERTON, J. *Second Report on MINOS.* Report No. 6, Working Environment Research Group, University of Bradford, 1984. (b)

BURNS, A., NEWBY, M., & WINTERTON, J. The restructuring of the British coal industry. *Cambridge Journal of Economics,* 1985, *9*(1), 93-110. In D. Cooper and T. Hopper (Eds.), *Debating coal closures: Economic calculation and the coal dispute 1984-5.* Cambridge: Cambridge University Press, 1988, pp. 253-277.

BURNS, T. (Ed.). *Industrial man.* Harmondsworth: Penguin, 1969.

CHILD, J. Managerial strategies, new technology and the labour process. In D. Knights, D. Collinson, and H. Wilmott (Eds.), *Job redesign: Organisation and control of the labor process.* Aldershot: Gower, 1985.

DICKSON, D. E. The morbid miner. *Edinburgh Medical Journal,* 1936, 696.

DIX, K. Work relations in the coal industry: The handloading era 1880-1930. In A. Zimbalist (Ed.), *Case studies on the labor process.* New York: Monthly Review Press, 1979.

DOUGLASS, D. *Pit life in County Durham.* Oxford: Oxford University Press, 1972.

DOUGLASS, D. The Durham pitman. In R. Samuel (Ed.), *Miners, quarrymen and saltworkers.* London: Routledge and Kegan Paul, 1977, pp. 205-295.

EDWARDS, C., & HEERY, E. *Management control and union power: A study of labor relations in coal mining.* Oxford: Clarendon, 1989.

FINE, B., O'DONNELL, K., & PREVEZER, M. *Coal Before Nationalisation.* Discussion Paper No. 128, Department of Economics, Birkbeck College, December 1982.

FINE, B., O'DONNELL, K., & PREVEZER, M. *Coal After Nationalisation.* Discussion Paper No. 138, Department of Economics, Birkbeck College, March 1983.

FORMAN, C. *Industrial town.* St Albans: Granada, 1979.

GRIFFIN, A. R. *The miners of Nottinghamshire.* Nottingham: Nottingham Printers 1955.

GOODRICH, C. *The frontier of control.* London: Bell, 1920.

GOODRICH, C. *The miners' freedom.* Boston: Marshall Jones, 1925.

HALLIDAY, J. L. *Psychosocial medicine: A study of the sick society.* London: Heinemann, 1948.

HANDY, L. J. Absenteeism and attendance in the British coalmining industry: An examination of post-war trends. *British Journal of Industrial Relations,* 1968, *6*(1), 27-50.

HANDY, L. J. *Wages policy in the British coalmining industry.* Cambridge: Cambridge University Press, 1981.

HARRISON, R. *Independent collier: The coal miner as archetypal proletarian reconsidered.* Hassocks: Harvester, 1978.

HEATH, R. I. The National Power Loading Agreement in the coal industry and some aspects of workers' control. *Trade Union Register,* 1969, 185-200.

HEPWORTH, R. et al. The effects of technological change in the Yorkshire coalfield 1960-1965. In D. M. Kelly and D. J. C. Forsyth (Eds.), *Studies in the British coal industry.* Oxford: Pergamon, 1969, pp. 221-237.
HEYCOCK, S. Effects of Collective Bargaining Structures on the Nature of Industrial Conflict. Ph.D. thesis, University of Leeds, 1986.
HEYCOCK, S., & WINTERTON, J. The Labour Process at the Coal Face: Evidence from One Hundred Years. UMIST/ASTON Organisation and Control of the Labour Process, 7th Annual Conference, Manchester, 29-31 March 1989.
HUGHES, J., & MOORE, R. (Eds.), *A special case? Social justice and the miners.* Harmondsworth: Penguin, 1972.
JONES, A. D. W., QUINN, J. J., & WOOLLEY, K. M. *Evaluation of coal winning technology.* London: Technical Change Centre, 1984.
KELLY, D. M. The process of mechanisation in British coal mining since 1945. *Economic Studies,* 1969, *4,* 135-151.
KERR, G. L. *Practical coal mining: A manual for managers, undermanagers, colliery engineers and others.* London: Griffin, 1921.
KRIEGER, J. *Undermining capitalism: State ownership and the dialectic of control in the British coal industry.* Princeton, NJ: Princeton University Press, 1983.
LEMAN, S., & WINTERTON, J. New technology and the restructuring of pit-level industrial relations in the British coal industry. *New Technology, Work and Employment,* 1991, *6*(1), 54-64.
LIDDELL, F. D. K. Attendance in the coal-mining industry. *British Journal of Sociology,* 1954, *5*(1), 78-86.
MEIKLEJOHN, A. History of lung diseases of coal miners in Great Britain: Part III, 1920-1952. *British Journal of Industrial Medicine,* 1952, *9*(3), 208-220.
NATIONAL COAL BOARD. *Report and accounts 1967/168.* London: NCB, 1968.
NATIONAL COAL BOARD. *Mechanisation profile.* London: NCB, 1971.
PAGE ARNOT, R. *The miners: Years of struggle from 1910 onwards.* London: Allen and Unwin, 1953.
PAGE ARNOT, R. *The miners in crisis and war from 1930 onwards.* London: Allen and Unwin, 1961.
PAYNTER, W. *My generation.* London: George Allen and Unwin, 1972.
PEEL, R. *An elementary text book of coal mining.* London: Blackie, 1893.
PENN, R., & SIMPSON, R. The development of skilled work in the British coal mining industry, 1870-1985. *Industrial Relations Journal,* 1986, *17*(4), 339-349.
PUGH, D. S. *Organization theory: Selected readings.* Harmondsworth: Penguin, 1971.
REID, C. *Coal mining: Report of the technical advisory committee on coal mining.* London: HMSO, 1945 Cmd. 6610.
RENOLD, H. The nature and position of skill in industry. *Economic Journal,* 1928, *38,* In C. Moore (Ed.), *Skill and the English working class, 1870-1914.* London: Croom Helm, 1980, p. 16.
ROSE, M. *Industrial behaviour: Theoretical developments since Taylor.* Harmondsworth: Penguin, 1975.
RUTLEDGE, I. Changes in the mode of production and the growth of "mass militancy" in the British mining industry 1954-1974. *Science and Society,* 1977, *41,* 410-429.
SAMUEL, H. L. *Report of the Royal Commission on the Coal Industry (1925).* London: HMSO, 1926 Cmd. 2600.
SAXENA, S. K. *Nationalisation and industrial conflict: The example of British coal mining.* The Hague: Nijhoff, 1955.
SCOTT, W. H., et al. *Coal and conflict.* Liverpool: Liverpool University Press, 1963.
SEARLE-BARNES, R. G. *Pay and productivity bargaining: A study of the effect of national wage agreements in the Nottinghamshire coalfield.* Manchester: Manchester University Press, 1969.
SILVERMAN, D. *The theory of organisation: A sociological framework.* London: Heinemann, 1970.

SIMPSON, R., & PENN, R. The Development of Skilled Work in the Modern British Coal Mining Industry: The Case of Maintenance Work. UMIST/ASTON Organisation and Control of the Labour Process, 5th Annual Conference, Manchester, 25-27 March 1987.
STEWART, W. D. *Mines, machines and men.* London: King, 1935.
TAYLOR, A. J. Labour productivity and technological innovation in the British coal industry, 1850-1914. *Economic History Review,* 1961, *14*(1), 48-70.
TOMANEY, J., & WINTERTON, J. The Transformation of Work? Technological Change and the Reorganisation of Work Practices in the British Coal Mining Industry. International Sociological Association 12th World Congress, Madrid, 9-13 July 1990.
TOWNSEND, J. F. *Innovation in coal mining machinery: The Anderton Shearer Loader.* Occasional Paper No. 3, Science Policy Research Unit, University of Sussex, 1976.
TREGELLES, P. Memorandum No. 59, House of Commons Select Committee on Energy. *The Coal Industry.* HMSO, 1986 *II,* 312-314.
TRIST, E. L. The Professional Facilitation of Planned Change in Organizations. Reviews, Abstracts, Working Groups: XVI International Congress of Applied Psychology, Amsterdam: Suets and Zeitlinger, 1968, pp. 111-120. In V. H. Vroom and E. L. Deci (Eds.), *Management and motivation: Selected readings.* Harmondsworth: Penguin, 1970, pp. 349-363.
TRIST, E. L. Assumptions of ordinariness as a denial mechanism: innovation and conflict in a coal mine. *Human Resource Management,* 1989, *28*(2), 253-264.
TRIST, E. L., & BAMFORTH, K. W. Some social and psychological consequences of the longwall method of coal getting. *Human Relations,* 1951, *4*(1), 3-38.
TRIST, E. L., HIGGIN, G. W., MURRAY, H., & POLLOCK, A. B. *Organizational choice.* London: Tavistock, 1963.
WILLIAMSON, B. *Class, culture and community: A biographical study of social change in mining.* London: Routledge and Kegan Paul, 1982.
WILSON, J. H. *New deal for coal.* London: Contact Publications, 1945.
WINTERTON, J. The trend of strikes in British coal mining, 1949-1979. *Industrial Relations Journal,* 1981, *12*(6), 10-19.
WINTERTON, J. Computerised coal: New technology in the mines. In H. Beynon (Ed.), *Digging Deeper: Issues in the Miners' Strike.* London: Verso, 1985, pp. 231-243.
WINTERTON, J. The Effect of New Technologies on the Productivity and Production Costs of the British Coal Mining Industry. Report No. 12, Working Environment Research Group, University of Bradford, 1988 (presented to House of Commons Select Committee on Associated British Ports (No. 2) Bill and North Killingholme Cargo Terminal Bill, 13 December 1988).
WINTERTON, J. Private power and public relations: The effects of privatisation upon industrial relations in British Coal. In G. Jenkins and M. Poole (Eds.), *New forms of ownership.* London: Routledge, 1990, pp. 134-150.
WINTERTON, J. Human factors and reliability in colliery maintenance. *International Journal of Quality and Reliability Management,* 1991, *8*(2), 52-57. (a)
WINTERTON, J. Flexibility, new technology and British Coal. In P. Blyton and J. Morris (Eds.), *A flexible future? Prospects for employment and organization.* Berlin: de Gruyter, 1991, pp. 275-294. (b)
WINTERTON, J., & WINTERTON, R. *Coal, crisis and conflict: The 1984-1985 miners' strike in Yorkshire.* Manchester: Manchester University Press, 1989.
WINTERTON, J., & WINTERTON, R. Strategic Implications of Proposed Colliery Closures. Report No. 1, Work Organisation Research Unit, University of Bradford Management Centre, 1992.
WOODWARD, J. *Management and technology.* London: Department of Industry, 1958.
YARROW, M. The labour process in coal mining: Struggle for control. In A. Zimbalist (Ed.), New York: Monthly Review Press, 1979, pp. 170-192.

ACKNOWLEDGMENTS

Two anonymous referees and the editor made helpful suggestions for revisions to this paper, and I am grateful to Ruth Winterton, Leeds University, for advice on specific improvements.

BIOGRAPHICAL NOTE

JONATHAN WINTERTON served his time in the engineering industry as an instrument maker before obtaining a first class honours degree in Industrial Technology at Bradford University in 1976. He proceeded to higher degrees in Industrial Relations with a Masters from the London School of Economics in 1977 and a Ph.D. from Leeds University in 1990. For 10 years, he was Lecturer in Industrial Technology, and since 1990 has been Lecturer in Industrial Relations at the University of Bradford Management Centre, where he coordinates the Work Organisation Research Unit. He has been involved in education and research with the National Union of Mineworkers since 1981 and has published extensively on the coal industry. He is co-author (with Ruth Winterton) of *Coal, Crisis and Conflict: the 1984-185 Miners' Strike in Yorkshire* (Manchester University Press, 1989). His current research interests include the effects of economic restructuring on industrial relations.

Human Relations, Vol. 47, No. 1, 1994

Research Note

National Attitudes to Competitiveness, Money, and Work Among Young People: First, Second, and Third World Differences

Adrian Furnham,[1,4] Bruce D. Kirkcaldy,[2] and Richard Lynn[3]

Over 12,000 young people from 41 countries on all five continents completed questionnaires measuring such things as the work ethic, achievement motivation, competitiveness, and attitudes to money and saving. Attitudes to competitiveness, money, and saving were clearly and logically related to gross domestic product and economic growth over a 10-year period. The European nations (N = 16) had lower scores on these dimensions than the non-European nations (N = 27). Countries from North and South America scored highest on work ethic and mastery while Far and Middle Eastern countries' young people reported highest competitiveness and acquisitiveness for money. These results are discussed in terms of the limited research in this field.

KEY WORDS: work ethic; motivation; competitiveness; money.

INTRODUCTION

For over 40 years psychologists have attempted, through multivariate statistics (primarily factor analysis), to discover the basic cultural and socioeconomic dimensions underlying various nations (Cattell, 1949, 1950). Possibly because rather different statistical measures have been used (and because the data on different nations have not been comparable) various rather different patterns have emerged (Griffeth, De Nisi, and Kirchner, 1985).

Cattell's work is typical in the area. Cattell, Graham, and Woliver (1979) found 21 interpretable factors from a factor analysis of 82 social,

[1]Department of Psychology, University College London, Gower St. London, WC1E 6BT.
[2]University of Bochum, Germany.
[3]University of Ulster, Coleraine, Northern Ireland.
[4]Requests for reprints should be addressed to Adrian Furnham, Department of Psychology, University College London, Gower St. London, WC1E 6BT.

0018-7267/94/0100-0119$07.00/1