Reluctance to Innovate: A Case Study of the Titanium Dioxide Industry

DALLAS HANSON, JOHN STEEN & PETER LIESCH

ABSTRACT *An autopoietic explanation is offered to explain the reluctance of a major international manufacturer of titanium dioxide to adopt a production process that might have enabled it to retain competitive advantage. Alternative explanations which focus solely on economic considerations and innovation difficulties are discussed, but it is concluded that they are merely part of an autopoietic explanation of a cultural blanket which engulfed the organisation. To support the argument, case evidence is presented on Tioxide's operations with a focus on Burnie, Tasmania.*

Keywords: autopoietic, diffusion, innovation, organisational culture, titanium dioxide.

Introduction

The titanium dioxide (TiO_2) industry has been of worldwide importance since the first production of this pigment in 1912. This industry provides an ideal case to examine several issues in the innovation and diffusion of technology. In this article the focus is on the two largest TiO_2 producers, Tioxide and Du Pont. Apart from the fact that these two companies alone account for just under 50% of global TiO_2 production,[1] they provide useful case material because of the major historical differences in their respective abilities to adopt important innovations.

The term innovation is used here to mean the bringing of new ideas into an organisation in order to resolve problems.[2] Whilst novel to the organisation that innovates, these may be an imitation or a minor adaptation of ideas or things that exist elsewhere.[3] In this case, the aim is to offer an account for Tioxide's failure to innovate, laggardly behaviour that extended over a 40-year period.

The history of TiO_2 manufacturing can be crudely broken into two phases based upon the dominant manufacturing method. The first involved the diffusion of the sulfate process for the production of TiO_2 which dominated the pigment industry until 1952.[4] The second phase coincides with the introduction and gradual diffusion of the chloride process for TiO_2 production. In this article, these phases are discussed before focusing the analysis on the reasons for Tioxide maintaining a sulfate process despite strong pressures for change from the social and political environment. It is proposed that neither economic considerations nor innovation difficulties explain well the laggardly behaviour of Tioxide in the adoption of the chloride process and that the answer lies more within the culture of the organisation.

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TiO_2 Production by the Sulphate Process

The origins of titanium dioxide manufacturing can be traced to original research by A.J. Rossi, a French chemist employed by The Titanium Alloy Manufacturing Company at Niagara Falls, New York. In 1908, Rossi prepared a relatively pure sample of titanium dioxide and immediately recognised its outstanding commercial possibilities as a white pigment. Titanium dioxide was more opaque and relatively non-toxic compared to the lead- and zinc-based pigments which dominated the market at the time. After a systematic research programme, Rossi and co-workers settled upon a pigment product containing 25% titanium dioxide. Commercial production of titanium dioxide began at Niagara Falls in 1918.

Around the same time (1908), the Norwegian government commissioned a report to investigate possibilities for the commercial utilisation of extensive deposits of ilmenite (approximately 50% titanium/50% iron). By 1912, the investigation had realised a method for the production of pure white titanium dioxide which was implemented on a commercial scale almost simultaneously with the Niagara Falls development. Unlike the Rossi process, the Norwegian method was a true sulfate process whereby ilmenite was heated with strong sulfuric acid to produce soluble titanium and iron sulfates. These products could then be separated so that the titanium sulfate could be converted to titanium dioxide. In order to accelerate the commercial development of the titanium pigments, the independent American and Norwegian interests agreed to collaborate in 1920. The terms for this cooperation included cross-licensing of patents as well as mutual exchange of technical information and operating experience.

These early developments in the titanium pigment industry indicate a 'fluid stage' prior to 1920. According to Moenaert *et al.*,[5] product development will dominate this stage as market needs are not yet clearly defined. The fluid phase is characterised by flexibility, entrepreneurship and informal relations. Of these characteristics, informal relations and informal networks may have played the critical role in the rapid diffusion of both product and process,[6] as W.S. (Bill) Robinson's experience indicates. Robinson was the product champion who pushed the idea of TiO_2 forward in Great Britain. In his memoirs, he recounts the early moves that ultimately resulted in the formation of British Titan (later Tioxide). A Norwegian friend, Jens Beer, burst into Robinson's London Office:

> Bill, you must come to Norway with me; I want you to join in visiting Fredrikston to inspect a product my friend, Dr Jebsen, has invented. I think there is a fortune in it.[7]

Impressed, Robinson put the idea before the initially disinterested Board of his firm, the National Smelting Company. His account of the manoeuvring that finally led to Titan's formation consistently emphasises these informal contacts. For example, he only wanted the British Empire's rights and wanted to 'bring in my close friends, the National Lead Co. of the USA for the rights in the rest of the world'. Later he recounts how he personally warned the Norwegian Jebsen of the dangers of his policies.

National Lead already had a stake in the production of TiO_2 having began production in 1925 at the Niagara Falls plant using Rossi's original idea. They were responding quickly to the threat posed to their lead business by TiO_2's effectiveness in paint production, in particular, its non-toxic nature. In 1920, they had purchased a substantial share in the Niagara Falls-based company, and in 1927 brought a controlling share in the original Norwegian company, Titan Co. A-S.

Robinson's role as champion and political operator was significant in this period. He claims to have put the idea of using the Norwegian TiO_2 process to his friends at National Lead and later to have been instrumental in organising the new British Titan Products. This was a joint venture between his own organisation (17%), Cookson (17%), ICI (17%) with 49% to National Lead. In this arrangement, Robinson's National Smelting Company and the USA's National Lead were a dominant coalition arranged informally. According to Robinson, 'they placed their shares and ours in a voting arrangement based on mutual trust', with the three-eighths of the USA company's voting rights held in the name of the first chairman, Bill Robinson. E.I. DuPont de Nemours and Company (DuPont) did not begin production of TiO_2 until they purchased the Krebs Pigment and Colour Corporation in 1943. They were at that time in direct sulfate process competition with Titan.

A major TiO_2 product innovation was commercialised in 1941 with the production of a different TiO_2 crystal with better overall pigment properties. This form of pigment, called rutile, could be produced after modification to the sulfate process. At this time, the technology could reasonably be termed mature.

Tioxide has since pushed an aggressive internationalisation strategy by setting up sulfate process factories in Canada, South Africa, Australia and France by the end of the 1960s.[8] This was followed by expansion into Spain (1976) and Italy (1982). The political and social backdrop for this expansion featured two major upsurges of environmental activism. The first, starting in the late 1960s and continuing through to the 1970s, sensitised large sections of the globe to environmental problems caused by industrial activity. Highlighted were Rachel Carson's *Silent Spring*,[9] which aroused widespread suspicion of chemical production; the Club of Rome's predictions of resource depletion; and Paul Ehlich's work on global population pressure. The second wave started in the mid to late 1980s and featured globally 'green' political activism, especially in Europe and Australia, with a late peak in the USA. Both waves had (lagged) political impacts that, as shall be seen, restricted sulfate production of TiO_2.

ICI gained complete control of Tioxide in December 1990 and Tioxide has since operated as a relatively independent global business within the ICI system. The purchase price for the company was $311 million which was well below the $700 million estimate by market observers,[10] perhaps reflecting uncertainty about Tioxide's future difficulties. Under the ownership of ICI, a more active Tioxide has made investments in plant processes, product development and environmental management, mainly to comply with European Community regulations. At the time of sale, it was estimated by the former stakeholders, Cookson, that these investments would cost a little under $1400 million. By comparison, ICI's estimate of the upgrade cost was closer to $400 million. Tioxide's sole reliance on the sulfate process also ended soon after ICI's takeover. They reportedly had a chloride route available in 1988[11] but had chosen not to adopt this technology. In 1991, Tioxide's Independent Chlorination and Oxidation (ICON) process was commissioned at Greathan but went little further than large pilot stage.

In the face of increasing costs of production by the sulfate process, Tioxide abandoned a 50-year tradition and purchased chloride process technology in 1993 by entering into a joint venture with NL industries at a cost of $200 million for purchase of a large US plant. To date, this remains Tioxide's only large production capacity based upon the chloride process. However, the recent decision by ICI to divest Tioxide[12] (February 1997) after their extensive investment and upgrade program casts doubt upon the long-term competitiveness of Tioxide. Arguably, this program has been at least 10 years too late. Furthermore, the ICI-instigated investment and upgrade strategy is unlikely to alter the core of Tioxide's problems.

The Chloride Process for the Production of TiO_2

The basic research that founded the chloride process for the production of TiO_2 appears to have been sponsored by a minor player in the industry, The Pittsburg Plate Glass Company, around 1940.[13] It was reported that the company had large quantities of excess chlorine and was keen to find a profitable use for this by-product.

By the late 1940s, Du Pont (which also had ready access to large quantities of chlorine) had also become interested in the chloride process, and in 1948 a commercially viable process was developed at Edge Moor, Delaware. The chloride process, as developed by Du Pont, had two significant features. First, the process enabled the direct production of high grade rutile TiO_2 with excellent pigment quality. Second, the chlorine was recycled in a continuous process, with minimal pollution. On the other hand, the sulfate route did not allow the recovery of sulfuric acid which was usually discharged into the sea along with iron waste. Although environmental considerations were not a high priority at that time, this gradually became a significant advantage over the sulfate process. More recently, Du Pont have claimed that the chloride process is more cost effective and more energy efficient when compared with the sulfate route for TiO_2 manufacture.[14] Du Pont also claim better quality and brightness qualities.[15]

Diffusion of the Chloride Process

Despite these advantages, the chloride process acceptance by the industry has been slow. DuPont first produced TiO_2 commercially in 1950. By 1985 approximately 35% of global TiO_2 production was accounted for by chloride route factories. This figure had increased to 52% by 1993 and can be predicted to be about 60% by the year 2000.

A major pressure driving the diffusion of the chloride process has been the problem of sea disposal of waste products from the sulfate process. US titanium dioxide manufacturing is dominated by chloride process factories at the present time, partly because of stringent US environmental legislation introduced between 1980 and 1985. The closure of sulfate process factories around that time took place under conditions of low production profitability. In the late 1980s, the legislative pressures affecting the disposal of waste from titanium dioxide had also become an important issue in Europe. A report in 1988 by the Economic Commission for Europe on the use and disposal of wastes from titanium dioxide production noted that, 'the most important factor affecting (titanium dioxide) production and process in the near future is the obligation to reduce the discharge of production wastes by 1990, mainly those disposed of to sea'.[16] At this time the operations of the Tioxide company were still firmly based upon the sulfate process. As a consequence, Tioxide's entire global production was under pressure to reduce the discharge of waste acid and iron into the sea.

There are several separate examples of long-running disputes between Tioxide and governments around the world. For example, Tioxide's operation in Canada near Montreal disposed of acid and metal waste into the St Lawrence river. After negotiations with the Quebec government in 1986, Tioxide had promised to reduce waste emissions into the St Lawrence river by 85% before 1991. The result actually achieved by Tioxide was only a 50% reduction in waste and even this was mainly achieved by cutting production. Consequently, Quebec authorities served an ordinance on Tioxide Canada requiring the company to close the St Lawrence plant.

Tioxide's Burnie operation in Tasmania, Australia, also based on the sulfate process, had been running under special ministerial exemptions from the 1973 Environment Act allowing the disposal of waste into Bass Strait. After the ICI buy-out, a more compliant

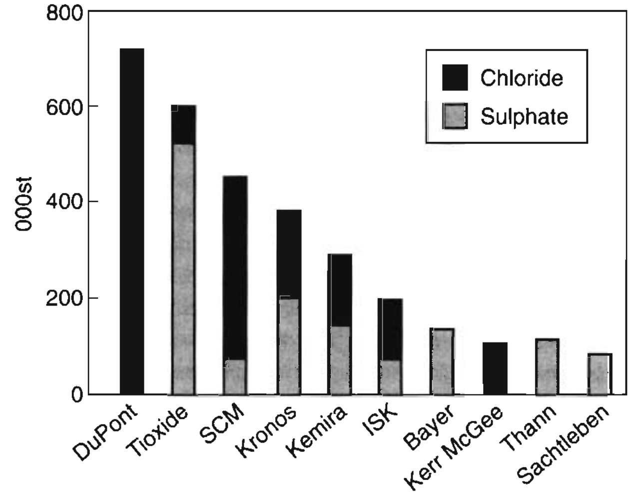

Figure 1. Top 10 TiO_2 producers.
Source: D. Gaskell, 'TiO_2—a brighter future for white pigment', *Chemistry in Britain*, June, 1995, p. 432.

Tioxide took action to reduce pollution, involving the community and a local environmental group in a consultation process that eventually led to a change in 1994 to a new low iron feed-stock, titanium slag. This had been used in other Tioxide factories for several years but in Burnie it was expensive. The factory stumbled on for only two more years before closure, never having been able to operate profitably with the new feed-stock. Basically, non-polluting for the first time, it was also uneconomic. These problems were not exclusive to Tioxide's sulfate-based operations. In 1991, it was estimated that most of the world's titanium dioxide production based on the sulfate process was unable to comply with environmental regulations and these plants were facing substantial compliance costs in terms of acid recycling.[17] This is related to the fact that recovered acid is three to five times more expensive than the use of virgin sulfuric acid that is disposed of at the end of the process.

Most titanium dioxide manufacturers have responded rapidly to the pressures facing TiO_2 production by the sulfate method, largely by adopting chloride technology. However, Tioxide has been remarkably slow to adopt chloride technology. A survey of production by the top 10 TiO_2 producers showed that Tioxide had anomalously low exposure to production using the chloride process.

The bar graph shown in Figure 1 demonstrates an unusual sulfate/chloride production split compared to other large companies such as Du Pont, SCM, Kronos and Kemira. This comparative production split is intriguing because Du Pont, Tioxide, SCM, Kronos and Kemira are all international companies and would therefore be faced with similar social and political demands for environmental responsibility.

Barriers to the Diffusion of the Chloride Process

The gradual diffusion of the chloride process is typical of the diffusion of technology in a mature industry. In their discussion of the diffusion of technological innovations, Gold *et al.*[18] suggest that managerial decisions concerning the adoption of major innovations may be divided into three types. These are: those involving *additions* to available capacity;

those involving the *displacement* of functioning facilities; and those involving the *replacement* of capacity withdrawals.

When faced with increasing pressure to comply with environmental legislation, the management of Tioxide appear to have had the option of adding to the available technological capacity. In 1987, a range of pollution control measures were being undertaken by Tioxide. Most of these measures involved attempts to recover acid or find alternative methods of waste disposal. In contrast, the installation of the chloride process at the expense of a functional sulfate plant represents a displacement of existing facilities. Prospective displacements tend to be confronted by obstacles that are generally not associated with capacity additions. For example, these include change-over costs involved in the adjustment of employment levels, job descriptions and skill requirements, production quotas and associated supervisory arrangements. Displacement also entails writing off undepreciated investment in existing facilities which is particularly unattractive in the TiO_2 industry because of the enormous capital investment in each titanium dioxide plant.

The decision model that appears to have been most applicable to the majority of TiO_2 producers is the replacement of the capacity represented by facilities based on the sulfate process. Replacement may occur under conditions of capacity shortage or after wear and breakdown of older existing capacity. Gold *et al.*[19] argue that under these circumstances, the bases for managerial choices are more likely to resemble capacity additions rather than the obstructions facing the displacement of existing facilities. Currently, the TiO_2 market is at a mature stage and is growing very slowly. It is possible, therefore, that a chloride technology will replace sulfate plants when these existing factories become old and redundant, a process followed by significant Tioxide competitors.

Whilst the Gold models provide a satisfactory description for slow diffusion at the industry level they do not provide a satisfactory explanation for the reluctance of Tioxide (at the firm level) to use the chloride process. The organisation failed to read clear signals coming from the social environment about difficulties inherent in sole reliance on the sulfate process. Tioxide's closure of its 40-year-old Burnie operation (Tasmania, Australia) represented an ideal opportunity to replace the plant's production capacity with production based on the chloride process. Instead, Tioxide chose to build a plant in Malaysia based on existing sulfate process technology. At this time, and for 20 years prior to it, industry consensus was broadly that the chloride process was superior. Industry comment at the time is clear:

> Most surprising is Tioxide's decision to opt for the environmentally less sound and generally more expensive sulfate route at the new plant.[20]

Their move contrasts with that of Natural Lead, who replaced two sulfate plants closed down in the USA by government, with a chloride plant. SCM made similar moves to phase out sulfate-route production, even at the expense of lower sales and profits in the short term.[21]

Explaining Tioxide's Laggardly Behaviour

Three major lines of explanation can be offered in analysing Tioxide's failure more actively to embrace the chloride process, or some other efficient non-polluting pigment-producing process. Economic reasons provide potential explanation given that a change to these processes would be expensive. Technical and other difficulties in innovating also provide a possible explanatory model, and analysis of the ultimately obstructive nature of the company's culture provides a final (and more compelling) line of argument. After separate discussion, these partial explanations will be integrated in a model which provides a convincing argument.

A solely economic explanation of Tioxide's performance initially appears attractive. Assuming an alternative was available—and, for the sake of discussion, it can be assumed for the moment that this is so—the replacement of any currently functioning sulfate plant with a chloride plant would be prohibitively expensive even for a large company such as Tioxide. The immediate cost would amount to multiple hundreds of millions of dollars but perhaps more significantly there would be change-over costs associated in adjustments to such things as employment levels, job descriptions and skill requirements and these would require new training programs and a range of other human resource management responses. As well, displacement of existing plants would entail the writing off of undepreciated investment in existing facilities, an unattractive move in the TiO_2 industry because of the huge investment in each plant.

At any point in time from the 1960s onwards these arguments may have appeared compelling. However, when a longer time-frame is introduced, these arguments are not as convincing. Tioxide plant and equipment were aging and could have been gradually replaced with an efficient chloride technology as opportunities to write off old plants became available. From the early 1970s onwards, the difficulties in complying with environmental laws and continuing pressure from local communities provided constant reminders that some change was required. As already noted, the Tasmanian plant was unable to comply with the conditions of the Environmental Act passed in 1973 and required a range of specific exemptions from its provisions in order to carry on. Exemptions from air pollution and pollution of the seas were the most significant of these, but there were more than 10 exemptions in operation in the mid-1970s. The company's response was to 'fine tune' the existing operation of a plant by then more than 20 years old. This led to a gradual reduction in the numbers of exemption extending up until the mid-1990s when only the major exemption covering major pollution of coastal waters remained.

This is the pattern of operation throughout the globally spread Tioxide group. Up until at least the early 1990s, the company operated on the assumption that this was a mature industry and that they were using a competitive technology, and therefore that the appropriate strategy was to aim for steady profits without the need for major innovation. The test for the routinised power of this assumption came in the late 1980s when Tioxide responded to Asian demand for TiO_2 with a new plant in Malaysia. Major investment was involved and the new plant was based on the sulfate process, using the best possible sulfate technology installed with assistance of Tioxide's best technical people, a number of them from the aging and relatively small Burnie plant which was by then obviously in economic decline. The economic explanation is ultimately, therefore, unconvincing. Tioxide persist with a sulfate process that is increasingly uncompetitive because of the costs of environmental compliance and they answer the challenge of emerging markets with their generations old technology even though it is increasingly marginal in the overall world pattern of production for TiO_2.

Another explanation comes with consideration of the technical difficulties of innovating. The history of TiO_2 processing makes this clear. The sulfate process was developed first and uses mainly ilmenite containing around 50% TiO_2. Tioxide refined this method early and it was arguably technologically mature by the mid-1950s. The chloride process was invented in 1952 as Du Pont took advantage of excess chlorine in developing a process that uses a richer ore as feed-stock but produces significantly less pollution than the sulfate process. It was refined by 1975 and can be considered a mature technology from that time.

Up until the early 1970s, it is perhaps not surprising that Tioxide failed to follow Du Pont. The sulfate process was technologically mature, could use lower grade ilmenite and yielded good returns in a mature industry. In addition, Du Pont's competitive advantage stemmed not only from the chloride technology by from their supply of chlorine, and this could not be readily duplicated. This does not, however, mean that entry into chloride-based production could not have taken place. Indeed, by the late 1970s the knowledge required was spreading as Kerr McGee, via a network of international joint ventures, established a variation on Du Pont's chloride process as another globally competitive TiO_2 technology.[22]

The threat to Tioxide, however, came not from the capacity of competing technologies to produce better pigment but more from changes in the TiO_2 industry's external environment which rendered pollution from the sulfate process a socially and politically significant factor. By the 1970s, global concern for the natural world was obvious. Indeed, the early 1970s produced the first of the two peaks in the global environment consciousness identified in previous discussion. This provided Tioxide with clear signals that their pattern of operation was problematic. The Tasmanian Environment Act 1973, for example, provided a clear indication, sending a message that was echoed in the other countries in which Tioxide then operated.

In this situation, the Tioxide response was three-sided. Firstly, they defended existing operations at both a political and a social level. In Tasmania, for example, this was successful and led to a 25-year history of operations with a government exemption to the Act obtained on the argument that compliance with its provisions was impossible and that regionally-significant employment levels could only be retained if the company was given more time to resolve its problems. At the same time (and as a second line of response), the company became more alert to environmental difficulties caused by their operations. In Burnie, for example, marine surveys offshore from the plant started in the early 1970s, a process first made public in the first publicly available Environmental Performance Site Report made by that operation in 1993. The company had evidently sensitised to environmental concerns, but apparently was unwilling to act on them.

The third response is one more typical of situations in which a competing technology is new and still developing towards maturity. Cooper and Schendel[23] suggest that in such cases the threat tends to come from companies outside the mature industry and is associated with technologies that are relatively expensive. In this circumstance, they suggest that threatened firms counter with renewed attention to existing technology even when this does not appear logical. The Tioxide response, despite different circumstances, has been similar. Their competing technology was already mature and their competitor clearly within the same industry, but the response to challenge was to fine-tune their plants, rendering them marginally more efficient and less polluting. After the takeover by ICI in 1990, this was particularly apparent. Their UK plants, for example, started to recycle waste acid, gaseous emissions were dealt with in several factories and new feed-stock was used in Burnie. Much of this was forced on them at this time by environmental regulations, but the company had been tinkering with operations in defiance of common sense since the mid-1970s. In any case, it is clear that technological difficulty was not the major reason for Tioxide's failure to follow the chloride route, through gradually introducing it into their older plants. It is not, however, enough to suggest that this failure was simply illogical. In fact, it is fair to suggest that it did seem logical to several generations of Tioxide management. How could this be so?

A reasonable explanation may come with consideration of what Moenaert *et al.*,[24] following Galbraith and Kazanjian,[25] refer to as 'personal and emotional considerations' which hinder the decision by top management to innovate. The conjecture is that managers who have prospered with an existing technology are reluctant to adopt a new one. Does this fit the situation described, bearing in mind that it is being called upon to explain laggardly behaviour that extends through 40 years?

An Autopoietic Explanation

In addressing this question a variation of the autopoietic view is offered. First applied to social systems by Maturana and Varela,[26] autopoietic theory suggests that the relationship between an organisation and its environment is largely self-determined. Niklas Luhman,[27] for example, has used the notion in a grand analysis of society arguing that social subsystems such as the law and science are autopoietically closed. This means that information is internally constructed according to a specific set of understandings that are culturally defined (for example, the use of precedent in legal argument).

Applied at the organisational level, this means that information about the external environment is continually defined in terms of existing understandings: the old lens interprets a new world. This does not mean that change does not occur; indeed as Morgan[28] suggests, each organisation is in a continual state of flux as components within it respond (in their own terms) to challenges in their environment. Tioxide, for example, continually changes production levels to meet demand conditions and has closed factories as they have aged and/or failed to meet the requirements of the environmental regulations. Nor does it mean, as Khalil[29] suggests, that an 'organisation is stopped from command or authority'. Change by dictate is possible; indeed, in the world environment it is frequent, but all the time those in authority must deal with the existing lens and existing understandings of how the world operates. As a result, many organisations possess what Schein[30] refers to as a 'learning disability' in that they fail to see opportunities and threats emerging in the world.

A key to further understanding of this generic situation comes with consideration of the importance of language and communication in any change process. In the Krogh, Roos and Slocum[31] version of the autopoietic perspective, a distinction is made between data, information and knowledge. Data are elements of potential information, and books and technical reports become information only after a process of interpretation. Data can be 'latent', in which case their meaning can be unclear, requiring extensive discussion for a manager to turn them into information, or it can be 'manifest' in which case the meaning is relatively clear and it can be converted easily into information. The key to such conversion is 'languaging', basically a process of discussion.

In the Tioxide case, it is suggested that data about the advantages of the chloride process were latent and not converted into information by management and workers who were blinkered by a vocabulary and vision which was focused around the problematic sulfate process. The organisational culture of Tioxide created strong impenetrable boundaries that inhibited understanding of alternatives for 40 years. The tendency to autopoiesis in Tioxide was particularly strong. This is not to say that no-one in the Tioxide organisation had an understanding of the datedness of the sulfate process, but rather that organisational knowledge and antecedent information shared within the organisation did not provide legitimacy for ideas contrary to a sulfate-based culture. Hajer[32] provides some understanding of this situation with the concept of a 'discourse coalition', 'a group of actors who share an assembly of ideas, concepts and categories' used to give a phenomenon meaning. When the language that defines a particular discourse comes to dominate thinking in society and the way dominant institutions in that society work, the position is one of 'discourse institutionalisation'. In Tioxide, the discourse coalition arguably involved language focused on conservative adherence to the sulfate process, and the discourse institutionalisation made discussion of alternatives difficult.

The fact that from at least the early 1970s Tioxide had collected data that provided potentially instructive insights into the environmental impacts of their pollution is interesting when considered from this point of view. These were data that never became organisational knowledge. They did not translate into action because they were not legitimated by the discourse coalition. In this organisation, legitimated discourse related to their established sulfate technology and the basic conservatism of the generations of managers. Establishing this outcome definitely is difficult without access to internal memos and records of conversations, but useful indications of the situation can be gained from a range of publicly available sources. W.S. Robinson, Tioxide's early champion, said in his memoirs:

> The success of the British company [Tioxide] is common knowledge ... the conduct of the company's affairs was excellent in every way but one—it was never progressive enough! I had the temerity to emphasise this at the opening of the first Australian plant on site in Tasmania. I said it should have been at least twice as large. Far too many Britons in those days regarded any plant they put up in Australia as a definite threat to their own trade. This often left the door wide open to competition and eventually they got it.[33]

This conservatism has extended throughout the company's history and its technical counterpoint is well represented in the series of environmental reports produced by the company. In 1995, for example, they were still claiming that the environmental impact of the TiO_2 process was determined more by the choice of ore, the waste treatment techniques employed and the degree of co-product developed than the manufacturing route (sulfate or chloride). This is technically feasible but denies the reality of a heavily polluting sulfate process faced with a relatively clean chloride process. The difficulties and ultimate closure of Tioxide's Burnie plant when management finally altered operations so as to eliminate the need for their final (sea pollution) exemption demonstrates the obvious problem in arguing the position they put forward.

The Tioxide company, then, has been from its inception and throughout its history, a conservative company wedded to a specific technology. Despite a change in ownership to ICI, this has continued, probably assisted by the fact that ICI allows subsidiaries to operate as semi-independent entities.[34] Economic explanations partly account for its laggardly stance in innovation. Difficulties involved in innovating are also a partial explanation and it has been suggested that a compelling reason can be identified in the company's conservative culture, one wedded to the sulfate process that gave them a pre-eminent position in the early decades of the TiO_2 industry. These three levels of explanation seem complete when integrated, with economic and innovative difficulties legitimated by the conservative culture which operated as a 'blanket' protecting the positive image of the sulfate process held within the company. Responses to other elements of their industry, particularly to the external environment, were possible. They could penetrate the blanket, but issues implying major deficiencies in the sulfate process could do so only very slowly. Two categories of influence, therefore, operate in this situation; those which can influence operations quickly and fundamentally, and those which can influence slowly and in a peripheral sense. This situation is presented in Figure 2.

The mechanism for the operation of such a cultural blanket has been outlined. It relies

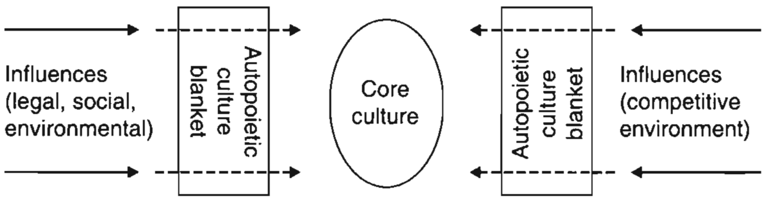

Figure 2. The effect of an autopoietic cultural blanket.

on a discourse coalition within this (or any other conservative technology-focused) organisation, and therefore on conversation within the organisation, that fails to convert data about blocked influences into organisational knowledge. This process is pervasive within such an organisation, involving more than (but including) the emotions and perceptions of top management. This does not imply any lack of training or acumen on the part of the staff, but merely a powerful culture at work.

It is probable that the conditions for it being set up in other organisations are generalisable from this case: a conservative organisation even in early market life; a technology with early dominance; fundamental challenge from a competing technology coming slowly into prominence; and enabling issues that have major impact on the utility of the core technology developing slowly. One of the ironies of a world economy that emphasises flexibility, responsiveness and accountability is that global patterns of change allow such organisations to survive by facilitating relocation of old technologies into new (and less strictly regulated) locations. Tioxide's move into Malaysia with what amounts to a new version of the old technology provides an illustration of this process.

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