*Essay*

# Repair in Socio-technical Systems

## The Repair of a Machine Breakdown that Turned into the Repair of a Shop

**Cynthia Colmellere**
*Paris-Saclay University*

**Abstract** This article aims to deepen our understanding of repair work in sociotechnical systems. It is based on three main bodies of literature, which are specifically attentive to materiality: STS studies on repair, studies of breakdowns and technological change in organisation studies and the sociology of work, and occupation studies in industrial workplaces. The present case study deals with a repair of a material device that is used by managers to repair the shop's organization and restore their authority in the workplace. However, this attempt to repair the shop jeopardizes the repair of the machine. It reveals that the repair of socio-technical system combine different lines of repair – material and organisational, mundane and transformative – which are for some of them complementary, divergent for others.

**Keywords:** repair; maintenance; organisation; opacity; sociotechnical systems.

**Corresponding author:** Cynthia Colmellere, Paris-Saclay University, SHS Department, Ecole Centrale Supélec, IDHES, ENS Cachan, UMR 8533 – Email: cynthia.colmellere@gmail.com.

## 1. Introduction

Failures and breakdowns in socio-technical systems are moments of disruption, vital to the understanding of the processes by which these systems actually work, are maintained, and evolve over time. These events can be seen as forms of "unblackboxing" (Graham and Thrift 2014, 8), for at least three reasons. First, even if the failure of a single machine is identified as the principal cause, unanticipated consequences for the rest of the system create a "tight coupling" (Perrow 1999) between its elements. Second, as repair becomes a major concern, this usually invisible work comes to the fore (Star 1999, 385). Third, investigations to identify the causes of breakdowns reveal patterns of organisation, work practices, and cultural processes in professional groups such as "normalisation of deviance" (Vaughan 1996) that lead actors to misperceive, misunderstand (Vaughan 1999) and ignore crucial elements (Turner 1978). As a consequence, the repair of breakdowns in socio-technical systems concerns both material and social order and consists in fixing social structures and practices as well as the defective machine.

The scope of repair and associated changes can vary. At one end of the continuum, repair can largely restore the status quo before the breakdown and preserve existing structures of practices and organisation. At the other end, repair can consist in major organisational restructuration, reallocation of human and economic resources, and modifications of control and decision processes, in order to make relationships between actors, as well as between actors and equipment, more ordered and predictable (Turner 1978). In this case, repair can be described as "the process communities and institutions engage in to sustain their existence, identity, and boundaries" (Sims and Henke 2012). Breakdowns in socio-technical systems can be compared to technological change analysed in the sociology of work and occupation and organisation studies (see for example Barley 1990; Orlikowski 2000). According to this perspective, breakdowns "will engender opportunities for social change to the degree that they open arenas of negotiation" within organisations (Barley 1988, 51). Their repair can be described as a process by which "technical constraints, social power, on-going actions and interpretations mingle to create social order" (Barley 1988, 52). Negotiations[1] consist in "carefully balanced discursive, institutional and material change" (Sims and Henke 2012, 326). However, negotiations can be conflictual for at least two reasons. First, the technology's multiple and contradictory implications for the organisation of work (Chateauraynaud 1991). Second, because, depending on the social and economic context, some actors may seize on the repair as an opportunity for more radical change in existing structures and practices (Sims and Henke 2012). In such cases, conflicts can occur because the redistribution of resources enhance or degrade the authority and position of groups in the division of labour.

In this article, my aim is to deepen our understanding of repair work in sociotechnical systems. When a major breakdown in a socio-technical system occurs, how do actors repair material and social practices and structures? How do they combine and balance these different dimensions of the repair work? How do they use repairs as opportunities for more extended changes in the workplace? Depending on the social and material context, what contradictions are they confronting with?

[1] In his article (1988), Barley named this perspective "interpretive materialism".

## 1.1. Presentation of the Case Study

To explore these questions, I study the repair process of a major breakdown in the biggest shop (54 employees, 7300 $m^2$, 6 floors) of an industrial pharmaceutical plant (650 employees). This study is part of a larger ethnography (2003-2006) (Colmellere 2008). Before being closed in 2009, this shop was in activity seven days a week, 24 hours a day. Started in 1986, it was dedicated to the production of two intermediate drugs (beta blockers and anti-inflammatory), over periods lasting four to six months. Even if extensively automated and computerized, the processes utilized presented dangers for operators' health and safety. Organic matter regularly clogged the pipes because of the ups and downs of the processes. This required manual interventions to clear products that were carcinogenic, had teratogen effects and could cause genetic mutations. Over the years, this shop gained a strong reputation within the plant for its unmanageable[2] and strike-prone production teams, and became known as the "Gallic Village".

The breakdown studied here occurred on April 17, 2004. It caused considerable disturbances to the workplace because it occurred during the start-up phase of a major modification project involving the replacement of the shop's computer systems to comply with European and U.S. Food and Drug Administration regulations. These regulations required that the new computerized system record and document data for each individual action during batch processes. As these records allow for extensive control over operators' actions, plant and shop managers considered this new computerized system as an opportunity to reinstate hierarchies within operators' teams and restore their authority over them.

In this shop, managed by a production engineer and a deputy plant manager, maintenance was not a key concern, despite aging and dilapidated equipment. Persistent and recurrent failures of routine equipment revealed that production workers institutionalized threats to equipment. As much as possible, production teams tried to postpone basic repairs (sensor failures, leaky pumps, etc.) until scheduled maintenance outages. They routinely ignored these failures and disconnected defective materials from the computerized control system. In addition, since 1990, daily repairs and scheduled maintenance had been increasingly outsourced. During production periods, sub-contractors performed repairs under the control of the production technician in charge of consignment and deconsignment. The two maintenance technicians dedicated to the shop were used to work far from the equipment. They had to manage contracts with maintenance companies, plan and prepare maintenance outage control, take care of complex equipment (like the "beast of grief") and perform major equipment modifications. In addition, traceability and feed-

[2] Over the last three years, three production engineers left the shop's management team because of difficulties in managing production teams.

back remained poor.

The breakdown occurred after an initial six-month period of equipment incidents and persistent IT outages. It concerned a complex and highly sensitive device – a nozzle[3] – tightly coupled with other equipment components. It was usually referred to as "K", after the name of the company that made its first version. Production workers discovered the failure as soon as they restarted production after the maintenance outage control. Screens indicated that the level of pressure increased in the K's main body i.e., the air-tight vacuum was impossible to maintain. However, neither data recorded nor local examinations were sufficient for operators to identify the breakdown causes. This failure exacerbated already tense relationships: workers vehemently insisted on the responsibility of the production engineer and plant management for the lack of resources to restart production under proper conditions.

The repair work – diagnostic phase and the repair itself – lasted three weeks, during which production was completely interrupted. After one day of trial and error to restart the "K", the production engineer called in the director of the maintenance department and the plant processes expert on a task force. After three weeks of false diagnoses and unsuccessful trials, the team despaired of finding a solution and finally decided to ask for help from the K's maintenance expert. The repair itself took a few hours. The technician diagnosed a small fix, which was performed by his colleague, the other maintenance technician dedicated to the shop. According to him, his colleague did it to improve the equipment's performance. The technician at fault was never officially penalized but members of the task force and their superiors emphasized his lack of skills. However, diagnostic difficulties and the repeated complaints of production teams revealed the shop's lack of resources for proper repairs and maintenance. Plant management – the plant director, the manufacturing director, and the technical services director – decided to strengthen shop management. They created a "plant management team" composed of the production engineer, the deputy plant manager and a maintenance engineer. In some respects, the maintenance manager succeeded in obtaining more resources. However, they made no changes to either the number of maintenance technicians dedicated to the shop or the sub-contracting conditions. The shop continued to be plagued by conflictual relationships between operator teams and management as well as equipment problems.

The dynamic of this repair presents an opportunity to explore socio-technical repair so as to deepen our understanding of combination between discursive, material and organisation changes. Therefore, I consider the degree to which their choices to perform technical repair and organizational repair resulted from social (Stroobants 1993) and power rela-

[3] A conduit with a variable cross-sectional area in which a fluid accelerates into a high-velocity stream (see McGraw-Hill Concise Encyclopaedia of Engineering, 2002).

tionships (Alsène 1990; Thomas 1994) in the shop and in the plant as a whole. The "beast of grief" case presents the story of an equipment repair that is used by managers to actually repair their shop's organization. In this case, repairing organization means repairing operators' material and social practices. According to managers, it consisted in restoring hierarchies within operators teams, between operators teams and the two shop's managers, and, moreover relationships in the workplace.

Compared with the cases studied in the literature dedicated to repair work, this case presents three major specificities that will guide my analyses of the concrete practices of diagnosis and repair. First, the repair of this "beast of grief" is more than the repair of a machine. "As a technology that became embedded in a matrix of interpretations, [the beast of grief] acquires the status of a social object whose meaning and use were progressively uncoupled from its physical design" (Barley 1988, 47). This machine is fragile and non-stabilized; as Denis and Pontille demonstrated for Paris subway signs, "[each] intervention inevitably goes with uncertainty about materials. Instead of being stable resources, the material properties of signboards are important issues of the maintenance work itself" (Denis and Pontille 2011, 7). In the case studied here, uncertainty is due to the equipment non-stability because of its transformations through one mundane maintenance operation to another. Thus, I will consider the representations associated with this material object and the way its various states are represented and evoked in the workplace.

Second, issues of power and social relationships are explicit, thanks to two interconnected aspects: the specific context within which the breakdown occurred and the status and position of the managers who participated actively in the repair. The context included the particular economic and social situation of the shop and the extended start-up phase of the new computerized system. This reinforced the degree to which these managers were caught up in the repair of the shop.

Third, this case presents a combination of repairs: material, organisational, mundane fixes and transformative operations, which complementarities and divergences have to be considered.

My paper is structured as follows. In a first part, I explore the relevant literature and outline the characteristics of the repair of breakdowns in socio-technical systems. I have drawn on three main bodies of literature specifically attentive to materiality: STS studies on repair, studies of breakdowns and technological changes in organisation studies and the sociology of work, and occupation studies in industrial workplaces. I first describe the characteristics of repair work. As the present case study involves actors who are not repair specialists, I outline the skills and issues specific to repairs in socio-technical systems. I emphasize the non-stability of technologies as a specific issue. I then provide an overview of evolutions in the organisation of maintenance activities in industrial sectors since the 1980s — an overview that reveals the link between the invisibility of repair work and organisational opacity. Finally, combining these points and preparing the discussion of actor choices in the empirical section, I explain how these evolutions call into question relationships in workplaces and organisations.

In the second part of the paper, I describe the methodology employed, providing additional context to make clear the conditions of my fieldwork in this shop and on this breakdown in particular.

The third part is empirical, divided into three sections. First, I describe the diagnostic work by focusing on material and discursive practices. Second, I draw links between the two interrelated dimensions of repair: material and social structures and practices. I insist on the fact that the organizational repair is based on an incomplete diagnosis of the social practices that caused the breakdown. I provide explanations of the managers' diagnosis of the breakdown as the consequence of individual error. Third, I focus on the way the maintenance engineer's choice (to reinforce maintenance management in the shop) go along with the production management willpower to restore authority over operator teams and to correct their practices. This combination ultimately served to repair the shop's material and social orders. In this empirical part, I specifically highlight the conditions of repair linked to the breakdown context: the opacity of maintenance and latent conflicts between management and operator teams.

Finally, I conclude with a discussion of the theoretical and methodological issues raised by the study of the repair of major breakdown in socio-technical systems within a framework that combines the sociology of work and occupations, organisation studies, and STS.

## 2.2. Repairing Breakdowns in Socio-technical Systems: a Review of Studies on Skills, Opacity, and Power

### 2.1. Drawing on Resources and Coping with Contingencies

STS studies of repair work analyse it as an on-going process of negotiation between humans with intentions (Akrich 1992) and non-humans, both considered as parts of a network. Combining this network perspective with sociology of action, this approach places particular emphasis on materiality. It analyses repair work as a blend of material and discursive practices that consist in taking care (Puig de la Bellacasa 2011) of fragile and vulnerable objects (Denis and Pontille 2011). It imports from ethnomethodology and studies of situated activity the emergent character of social order and the dialectical relationship between human activity and setting (see for example Suchman 1987; Hutchins 1995) – referring to the physical environment and the sets of social and material relations surrounding action – or workplace that constitutes a "network of associations between the social and material" (Henke 2000, 59). These studies emphasize a triangular relationship between technicians in charge of repairs, machines and users (or customers) (Orr 1996), based on discursive practices and on close connections between bodies and objects to repair (Henke 2000).

Repair work is composed of two main phases: diagnosis and the repair itself. Diagnosis consists in "the creation of a coherent account of the troubled state of the machine from available pieces of unintegrated information" (Orr 1996, 2). Both phases take place in settings and workplaces that are arenas (Dodier 1993) in which technicians perform "mediations" (Akrich 1993) between things and users in order to change their representation of objects and of the workplace. In this approach, repair work concerns not only machines but users as well (Thomas 1928, cited in Henke 2000), highlighting two main points: first, as mentioned in the introduction of this paper, the status of machines as "social objects"; second, the importance of the relationships between repair workers and users (Orr 1996) whose maintenance depends on the technicians' ability to take care of machines.

Therefore, improvisation, "bricolage", innovation and ingenuity are essential characteristics of repair work (Graham and Thrift 2007). Repair specialists are able to combine acute skills that are not completely explicit even for those who are experts (Orr 1996): kinesthesis, sensory-motor, discursive (Barley 1996). As emphasized in sociology of work and organisation studies on technicians, these skills are distributed (Cicourel 1994) and collective (Barley and Bechky 1994; Barley 1996). They are developed and maintained through the sharing of experiences with machines, people, workplaces and their relationships, relationships in the specialists' communities and professional networks, documents on repairs such as procedures, repair logs, repair sheets (Denis and Pontille 2014), and the maintenance of a shared history via "war stories" (Orr 1996). A skilled repair worker draws on a range of resources within the workplace and outside it, according to the level of difficulty of the breakdown and contingent circumstances.

What are the specific issues entailed in repairing breakdowns in complex socio-technical systems, like the one studied in this article? At this point, three major issues arise, linked to the fact that diagnosis and repair must be considered in the context of the system of which the broken machine is an interrelated component. First, as for copiers (Orr 1996) and signs (Denis and Pontille 2010), fixes and misuses of the machine are permanent issues in repair work. Technology remains unstable because transformed through one maintenance operation to another and eventual threats. Moreover, as shown in the literature on major breakdowns (Perrow 1999; Perin 2004), because component parts of socio-technical systems are tightly coupled, the act of fixing – with "technology that compensates for, repairs, or replaces faulty technology" (Perrow 1983, 525) – has two faces: a positive one because it consists in repairing; a dark one, because of its unanticipated and dangerous consequences for the system.

Second, in a certain sense, repair work is even more complicated when facing tricky issues where the relationship with users is at stake. There are few ways to escape, for example, as with copiers, replacing the machine to save the relationship with customers. Third, and linked to the previous point, repairs introduce changes to the workplace. Yet, organisation studies[4] based on the practices of people working to implement technological change highlight the interrelation between technological and social changes and explore this aspect thoroughly. Therefore, repairs in socio-technical systems question the combination of material and social components and the way they influence one another. Thus, to understand precisely how actors repair material social practices and structures in socio-technical systems, two questions must be addressed: to what extent does the technology (to be repaired) shape organisational choices (social structures and practices)? Conversely, how do existing organisation influences repair practices?

These issues are studied in the first two sections of the empirical part of this paper. I turn now to another characteristic of repair work that makes its consequences for systems difficult for actors to foresee: its invisibility and opacity.

## 2.2. Opacity

STS studies on machine and infrastructure repair work highlight its invisibility (Henke 2000; Graham and Thrift 2007; Graham 2010). They suggest that failures and breakdowns render these usually hidden aspects of organisational life visible. In several studies on technicians, bridging the sociology of work and occupations, organisation studies and the sociology of science, Barley insists on the status of technicians within organisations as one of the root causes of their invisibility. Technicians work at the interfaces, as intermediaries between groups of people and between people and objects, as "buffers" (Barley 1996, 420). As such, they connect the material world and they master with the symbolic world of the people for whom they work. Therefore, they must harness language, theories, plans, know-how, and tricks of the trade to perform diagnostics and obtain data that they then translate into a symbolic language accessible to their customers. As "brokers" (Barley 1996, 422), they also have to translate user needs, which requires establishing and maintaining strong relationships with their occupational community. Their opportunities for professional advancement are more constrained than for other occupations, especially in organisations where career opportunities are mainly hierarchical (Barley and Bechky 1994). However, repair specialists often prefer to remain in their teams and their community rather than becom-

[4] See Orlikowski and Barley (2001) for a synthesis of organisation studies in the field of information technologies, which takes into account the institutional context and the materiality of technologies.

ing managers or experts (Orr 1996). Quality work, the ability to fix tricky failures and cooperative relationships with customers are the main sources of professional recognition.

Even if invisible most of the time, repair workers are presented as powerful because organisations are vulnerable to the loss of their expertise. This gives them leverage to negotiate resources and working conditions (Crozier 1964; Shaiken 1984). Nevertheless, since the 1980s, industrial organisations have implemented changes in their structures and practices to the detriment of local repair and maintenance workers whose activities where not fully understood. This change affected resource allocation for repair and maintenance, relationships within workplaces and with machines.

As many studies of industrial organisation have shown, repair and maintenance activities have been pushed, since the 1980s, to the margins of industrial systems through progressive out-sourcing. Routine repairs and maintenance outage control operations have been increasingly entrusted to outside companies. Maintenance in local departments has been steadily reduced to control, preventive maintenance, planning, contracting and major equipment modifications. At the same time, group cohesion was gradually undermined. It became more difficult to ascertain and appreciate the condition of installations because knowledge about them became more difficult to gather. This knowledge was unequally distributed between the different groups of workers in charge of the different aspects of repair and maintenance: permanent employees of the plant, subcontractors of varying status depending on the terms of their contract. In addition, systems of traceability and accountability were not properly redesigned in light of increasing outsourcing. Despite successive improvements, local repair and maintenance workers face more technical and relational issues in their activities. Knowledge of local idiosyncrasies concerning equipment, practical know-how, and relationships between users and equipment became simultaneously more critical and more difficult to acquire and maintain.

These characteristics and the non-stability of technologies to be maintained have lead to the "opacity" of maintenance within industrial organisations (Hannan et al. 2003). It reinforces its invisibility and misunderstandings of what is entailed. Analysing the breakdown of the British Bank, Barings Brothers, Hannan et al. describe opacity as a consequence of organisational architecture, which can be extended to maintenance organisation in industrial socio-technical systems. They outline the characteristics that allowed a trader to operate and cause the demise of the bank. Firstly, people working in the organization had limited awareness about how different units in their organisation were interconnected and worked together. Secondly, the structure of the organisation was porous with no clear lines of responsibility and accountability. Thirdly, the matrix structure of trading activities does not work properly in practice because of confusion in lines of reporting, ambiguous responsibilities, lack of traceability and poor communication between different organizational sub-units.

The design of such organisational structures was the work of engineers and managers who considered technologies as stable despite successive repairs and considered repair work as "little more than applying procedures" (Orr 1996, 3) to solve problems that could be anticipated, described and decoded using procedures and guidelines (Duclos 1991). As a consequence, they neglected the workplace's characteristics as well as the distributional and collective dimension of knowledge.

These representations were reinforced by the extent of automation in modernising production processes. As many studies in the sociology of work have shown, industrial processes and organisations are adapted to the degree of automation (Naville 1963; Shaiken 1984; Terssac 1992; Stroobants 1993; Dodier 1995; Terssac and Maggi 1996). Organisation, working practices, technical devices and production facilities kept pace with a "chimerization" of industrial processes. Based on the model of oil refining, *fluidity* was expected even in processes including material and solid products (Vatin 1987). Computerized systems were commonly set up. Because of the economic, organisational and human costs of these systems, considerable resources were invested to enhance their reliability and performance. Dedicated technical and engineering departments were created. Production work became more and more abstract and issues of automation and control, especially man-machine interfaces, were established as priorities to the detriment of the enhancement of working practices in installations. "Silos" between design, production and repair activities were reinforced (Perin 2004).

The developments described above go a long way to explaining the invisibility of maintenance and repair. They consist in the redistribution of resources and changes in relationships within organisations. In the following sections, I examine the consequences of these changes on the influence and opportunities of actors involved in maintenance and repair.

### 2.3. Influence and Power

The opacity of repair and maintenance in the workplace and the developments in industrial organisation described above had crucial consequences on the working conditions, practices and the effective influence of internal repair and maintenance workers. It affected their relationships with users as well as machines. Because less numerous and cohesive, working far from the equipment, these workers had to find resources that were more individual and specific to the idiosyncrasies of the workplace, and to become more flexible. However, they lost visibility, recognition and power. Classic conflicts concerning the availability of machines and working conditions described in organisations studies (Crozier 1964; Bourrier 1999) became concealed. Actually, this is not to say that these workers completely lost resources or influence. I only mean to point out that even if they remained close to the "technicians" described in the literature, their influence was based on practices, relationships, and networks that are more difficult to identify. It explains why other workers and managers know so little about their work and practices, and sometimes disparage them. Combined with the dilution of workers' influence and the opacity of maintenance activities, this misreading creates an "area of uncertainty" (Crozier and Friedberg 1977). Non-specialists can then use repair work as a resource to serve their objectives, in the case studied here, other repairs.

Considering the importance of the issues of relationships within organisations outlined above and the characteristics of repair work in socio-technical systems described in the first section of this article, the questions that guide my investigation can be formulated in the following terms:

How do actors combine material and social structures and practices to repair breakdowns in socio-technical system? How do material characteristics, local social practices, structures (Alsène 1990) and relationships within the workplace compel their work?

I address these questions in depth in the empirical part of this article, and then further explore the way "technical constraints, social power and on-going actions and interpretation mingle to create social order" (Barley 1988, 52).

But let me first describe in further detail the methodology employed, and specifically the organisation and practices of repair and maintenance in the shop, in order to make clear the context in which I studied the "K's" breakdown.

## 3. Methodology

I began conducting ethnographic research on this shop in February 2003. I was able to gain access to this place after meeting the plant manufacturing manager, the shop manager (production engineer) and the computerized system project manager. Because of the risks, I underwent a medical examination and safety training. The reason for my fieldwork in this plant was that I was interested in major modifications in high-risk industries. More specifically, I wanted to study how technicians and engineers consider human and organisational issues during design projects. I chose this project because of its scope and the issues concerned: technological and organisational changes and the explicit management desire to enhance operator practices and restore their authority over production teams.

The breakdown concerned a nozzle, designed specifically for the shop, was equipped, improved and adapted over time according to the shop's processes, needs and optimizations. Usually referred to as "K", after the name of the company that made its first version, this machine was nicknamed by former and current shop workers the "beast of grief". According to the shop workers, "beast" derived from its "unpredictable", "capricious behaviour", due to its extreme sensitivity to external conditions (temperature, pressure, humidity). "Grief" referred to the consequences of its malfunctioning. If it did not work properly, the production process could not run. Moreover, any repairs or modifications were bound to have unexpected consequences for the entire shop and its activities. Such situations might have been frequent occurrences, because the machine had to be restarted after each maintenance outage control (three to four times a year). But, they rarely happened because one of the two maintenance technicians assigned to the shop had specific knowledge and skills to "domesticate and master the beast", in local parlance. Therefore, production operators and managers considered the "K" as a "black box" whose functioning was taken for granted and whose failure remained only a potential catastrophe.

When the failure of the "beast of grief" occurred (April 2004), I had already spent more than a year studying people at work in the shop and on the project. I had already observed small equipment breakdowns and significant failures in the new computerized system.

During my fieldwork, I used semi-structured interviews and non–participant observations of production, repair and maintenance activities, project meetings and computer programming work. I studied documents related to work in the shop and on the project: procedures, handbooks, guides, plans, and regulations. I gained access to all areas concerned: the main control room, the shop's equipment installations, its dedicated laboratory, the meeting room, the lounge area and the cafeteria. During the repair of the "K's breakdown, I observed formal and informal meetings, conducted interviews[5] with 20 people and observed them at work: production workers, managers, members of the task force, maintenance technicians, and the former shop maintenance engineer who was the expert on the "K".

When the breakdown happened, the production engineer had been working as shop manager for six months. The other members of the task force had been working at the plant for at least ten years. The two shop maintenance technicians were highly experienced. The one who identified the fix and solved the problem had been working at the plant for almost 40 years and as a supervisor for ten years. The technician who performed the fatal fix was less experienced. However, he had been working in the shop as a technician for five years and at the plant for more that twenty. Both had spent their entire careers working in maintenance departments in the chemical industry.

In my investigations, I was keen to resituate the breakdown and its repair in the larger project dynamics. For each actor I interviewed, accord-

[5] Despite my repeated and insistent efforts, the maintenance technician who did the fatal fix on the machine refused to meet me.

ing to the situation, I tried to understand what was at stake for them, their involvement in the repair work, their diagnosis of the breakdown, their contribution to decision-making, and the way they imagined subsequent operations. I interviewed production operators more specifically on what mattered most in the situation (of breakdown and repair), how they understood the breakdown, the work of the people involved in the repair, how they anticipated restarting production and the shop's activities with the K repaired and the new computerized system.

I will now move on to the empirical description, analysing actors at work in diagnosing and repairing the breakdown. Let me first provide further details about the resources that maintenance workers can employ in response to failures and breakdowns: observations revealed that routine repairs were performed under the control of production teams. Most of the time, they followed a request by operators to their colleague, the production supervisor in charge of consignment/deconsignment. These requests were written on dedicated forms or remained informal depending on the level of emergency and gravity as perceived by operators. The production supervisor would then contact the sub-contractors concerned and prepare their intervention: a formal authorization, the license to operate at the facility, lock-out/tag-out sheets. He entered in the shop logbook the nature of the intervention and the time (start, duration, end), its location, the number of people working, the specific risks. However, interventions were not systematically reported because operators sometimes asked subcontractors for them directly without mentioning it to the supervisor. In addition, traceability and feedback on repairs were not formally reorganised with the development of subcontracting and the number or the extent of repairs performed were not systematically reported in the dedicated logbook according to procedures.

Repairs are one of the items on the agenda of daily shop meetings. The deputy plant manager conducted these meetings, every day at 13:30. They consisted of a review of the actions completed, currently underway, and scheduled in the shop (production, quality of production, repair and maintenance operations). Maintenance technicians did not systematically participate in these meetings. Moreover, they spoke only if they were invited to do so, in answer to specific questions.

> Daily meeting, shop meeting room, November 11, 2013:
> Deputy plant manager: "Maintenance?"
> Maintenance technician: "I'll pass".
> Production supervisor, consignment-deconsignment: "I will clean the oven if I find one or two people tomorrow. There was a problem with the heating of the (equipment) 41. This morning, there was a strange noise so we added water but the noise did not stop. It was a defective chromatograph. There was no alarm, but I have a sense that there are failures. I got on the elevator; there were three serious drips at flanges so we just started. Still, I requested a top flange from the silo to avoid drips".

Local maintenance technicians were called for the repair of some specific equipment and to prepare and set up modifications. They prepared and reported repairs in the same way as described above. They used to consult production documents (procedures, manuals, etc.). However, they barely used the computerized system themselves to diagnose failures and test equipment. They asked operator teams, if necessary.

> Our work is based on what we see. We use the IT system very little. There are other signs that indicate what is happening: noises, smells, heat, etc. At the beginning, the system crashed all the time so it was hard for us to use. Now it has been stabilized, but we didn't receive any specific training. I learned some basics with colleagues (the electrical service instrumentation maintenance), but most of the time we avoid using it… We ask production staff, those who know how to use it. Usually it works well that way. (Maintenance technician, expert on the K)

They were used to cope with difficulties in gathering data and information, because operators were not cooperative.

The technician who solved the problem explained the main difficulties of diagnosis:

> One of our difficulties is the transparency of information. To solve technical problems, it would be easier if everyone would forget the idea that they were responsible. When a piece of equipment fails they are not necessarily responsible. For us technically, it would be easier if we had more information to diagnose and repair properly. When we are working on a problem, it is hampered by a lack of availability on the production side. (Maintenance technician, expert on the K)

They would document modifications using technical modification forms, investment demand forms, validation forms.

In addition, they were in charge of internal and external scheduled equipment inspections and their documentation. Finally, when interviewed, maintenance technicians regretted the loss of skills and knowledge of equipment and criticized the growing power of the companies contracted for maintenance.

Developing my empirical description further, I will now explain how production and maintenance managers repaired the K's breakdown and seized on it to repair their authority over operator teams and finally the shop itself. I first show that despite a highly structured and systematic process they failed to diagnose the breakdown. I then outline the ongoing collapse of the relationships between operators and production and maintenance management. In the second part, I describe the task force's partial diagnosis of social issues in the shop, analysing it in terms of individual and collective attempt to repair the shop's organisation. In the third part, I deepen this analysis to explore two issues: Why did the task force refuse to call for external help for three weeks? Why did they analyse the failure as the consequence of a single individual's faulty action? Finally, I have synthetized these results to show how production and maintenance managers focusing on the repair of the shop have jeopardized the repair of the breakdown.

## 4. Fixing the "Beast of Grief": toward a Repair of the Shop

### 4.1. Unsuccessful Technical Diagnosis

The repair consisted of the diagnosis and the repair itself. The task force began the repair with the diagnosis. They rapidly realized that the K's breakdown was an "un-described situation" and a tricky one. As Orr describes it, in the case of difficult diagnosis, "if the problem is not recognized, however, an analysis must be done using information form a variety of sources, and the most difficult diagnoses are those for which none of the information sources provides a clear answer" (Orr 1996, 115). However, for the three members of the task force, diagnosis and repair remained, for almost three weeks, a technical issue.

The three engineers organized their work to perform diagnostic tests according to three interrelated principles. First they gave priority to formal methods. Second they adhered to a work style based on compliance with rules and methods. Third, as a consequence of the first two points, they preferred heuristics derived from formal knowledge than those based on experience. Their work took place in a small meeting room, close to the main control room. At certain moments, as needed, they joined the main control room or equipment installations, in the K's area.

Now, I turn to their physical and discursive practices. They considered the K as if it was an isolated device, disconnected from the rest of the equipment, except for the computerized system. They started by gathering together the plans and schemas for the K and its operation as well as the modification and repair log which would turn out to be incomplete. Then, they began to work on the diagnosis itself. They followed a procedure they described as "normal" and "classic". Based on "functional analysis" - used to design new systems - it consisted of dividing the K into parts and examining and testing each to see if it runs properly.

> There, I intervened because we were not making any progress. This was the first time we met with big problems. I tried to understand the operation of the equipment K. I knew a little but I'd never seriously looked at it. I tried to understand how it was built and how it worked. With V (manufacturing engineer and head of the workshop), we understood that a parameter escaped us. In

> that case, I brought in the method. We checked all the equipment to be sure there were no abnormalities. Meanwhile, we had documentation on this type of equipment. (29/06/2004, Maintenance Engineer, Head of the Maintenance Department of the Plant)

The examination had a physical dimension but bodies where only partially engaged: most of the time, the maintenance engineer visited equipment installations in the K's area. He had a look at the parts that were tested and compared their appearance with descriptions on plans, schemas and documents. Observations revealed that he paid attention to the visible features but hardly used sensory-motor skills (sound, smell, etc.) to complete his examinations and pre-diagnosis. Neither he nor other members of the task force demonstrated any close connection to the machine through their bodies, and "the ability to make sense of subtle differences in the appearance of materials and the behaviour of machines" (Barley 1996, 425). The maintenance engineer reported his observations as factual descriptions, close to the formal description of procedures and technical descriptions like those written on schemas and plans. He detailed his observations in terms of conformity/differences with what was indicated on the documents. He described his practices as a "systematic" and "methodological" way of working.

To perform tests and gather and interpret data, the three engineers relied on two intermediaries: the new computerized system and two computer processes specialists. They asked the latter to participate because they did not know how to use the system to launch tests, experiments and batches, or how to read and interpret the information on the screens. However, they refined their practices while advancing through the diagnostic process.

In their initial statements, they attributed the same importance to all of the K's parts. They described the condition of its various parts and the way they functioned according to the manual's procedures and descriptions. However, after one week of systematic research, the test results and the study of the repair and modifications log helped them to identify the most sensitive parts of the machine. They determined the function that had failed and its cause: leaks in the machine made it impossible to maintain the airtight vacuum in the main body of the K. They then began to search for leaks. This part of their work consisted in a very long protocol, because it concerned each component of the machine. They inferred from these tests and from reports on previous modifications to solve this kind of problem that defective ejectors were the most probable source of leaks.

> After a physical inspection of the equipment, in a systematic and methodical way, after one week we had not found anything. We thought, it's not normal ... what is difficult is that you are under pressure to restart quickly. We are forced to go fast when I know from experience that we can spend a lot of time looking to the side of the target. (Maintenance Engineer, Head of the Maintenance

Department, task force)

However, because they were not sure of their diagnosis or of their proposed fix, they decided to ask for external help from experts at the company which designed and installed the K.

> *Task force at work, meeting-room close to the main control-room:*
> Maintenance engineer: "The problem is to maintain the vacuum; therefore, ejectors are needed. Perhaps we have to know more about the ejector failures".
> Production engineer: "Don't know…"
> Discussion revolves around the machine's plan to determine the part of the machine that caused the failure…
> Plant processes expert: "I am still not convinced… I don't know".
> Maintenance engineer: "Perhaps we can call the manufacturer of the K, they could tell us if the problem…"
> Production engineer: "We have no other option for the moment".
> …Pause
> The maintenance engineer called the specialists who designed device. He returned back to the team without any firm answer: "They said it was not the problem. Actually they think the problem is that we did so many modifications and improvements that it makes any diagnosis tricky. According to my description of the breakdown and of the efforts we have made until now, they said we could not infer that the ejectors are the issue".

At the beginning of the repair phase and during the entire diagnostic phase, members of the task force never asked operators to participate in the tests. However, as mentioned in the methodological section, maintenance technicians were used to doing so. Operators did, however, remain informed about the repair process. Every day, at the beginning of the production meeting, the deputy plant manager updated them on the progress of the diagnostic process. In addition, he filled out the shop's field notebook, noted the trials and results and provided specific instructions to follow, especially for evenings, nights and weekends.

> Ejectors were dismantled on K. Nothing to report, the result is always the same. So for this evening and tonight, make it work by supplying 18% of the VC (volume capacity)". Message signed by the deputy plant manager. (Extract from the shop's field notebook, April 20, 2004)

He mentioned in interviews the fact that he deliberately limited the information to facts in order to "preserve operator morale and keep them motivated for the restarting." This empirical statement shows that, in the minds of this actor and the task force, the most important element of relationships within the shop was authority based on credibility.

Observations in the workplace during this period showed that these practices deepened divisions in the workplace: divisions between management and operator teams, between design (computerized system replacement) and production. It widened the cracks in the relationship between operator teams and management and revealed the extent to which the relationship between maintenance workers and production were broken. I will now elaborate on these two points.

Even informed operators exhibited strong reactions to shop management and the task force. They considered that the failure prevented them from doing their jobs. They insisted on the strong constraints they were subjected to because of the combination of the K's failure, the unreliable new computerized system and defective shop materials:

> *This scene took place in the main control room. Operators explained their situation to me; two members of the task force are present.*
> "If the filter is running and the K works, we can start up. But we do not manufacture, that's not manufacturing!... If we put the product in a new filter and then it drips, it would be ok. But they do not want to put up the cash. We make the raw product with a Z (equipment), and its pure part with an ancient filter from the Middle Ages! The oven is fully loaded, a ton and a half rather than a ton! How can it work?"

Moreover, during one production meeting, they expressed resentment and doubts as to the task force's ability to solve the problem.

> *This scene took place in the main control room, operators complained to their manager (production engineer):*
> "Give us the means to do our job…the manufacturing director must provide money. Nobody cares about our situation here… it still doesn't work!"
> Production engineer, shop manager: "No, H [Maintenance Engineer, Head of the Maintenance Department] stayed twenty hours last week."
> Operator, loudly: "For what purpose? None!"

Two days later, operators mandated their union delegates to give the manufacturing manager a grievance letter. This deterioration of the situation changed the task force mind. They decided to call for help.

At this point, we have some concrete illustrations of engineers engaging in repair work to maintain a common objective, which was first associated with the replacement of the computerized system, of restoring management's authority in the workplace. More specifically, the members of the task force tried to demonstrate their capacity through actions guided by compliance with methods and procedures. With the help of two computer processes specialists, they worked to change operator representations of the computer system and its performance, their relationship to procedures, materials and practices. However, the task force did not succeed in diagnosing the cause of the breakdown. Because of the context in the workplace and because they stuck to compliance with rules and procedures, they preferred not to improvise fixes or "bricolages". They recognized their insufficient knowledge of the "beast of grief". But, they did not want to give operator teams further reason to criticize their actions and run the risk of a strike action.

They reached a point at which they had no other choice but to ask for external help. They called on the maintenance technician expert on the K, justifying this decision in terms of the need for a "fresh perspective" on the problem. The technician listened attentively to what had been done to examine and diagnose the failure. However, he went to the machine, inspected it meticulously and understood immediately what happened: a small modification – a small piece added - prevented the K from functioning. He took off the added device, checked and tested the K carefully, and restarted it successfully.

Concerning earlier vain attempts at a diagnosis, the technician pointed out the task force's misunderstandings and errors. In doing so, he emphasized the specific skills needed to repair the K. At the same time, he described divisions between production and maintenance and the local maintenance specialists' lack of credibility when dealing with sensitive equipment issues:

> They solved the most obvious issues but they didn't go to see and understand what was happening at the exit of the device…(where the small modification had been made).

He pointed out that some diagnostic errors where due to the methods employed. Because they studied the K as an isolated device, they had not noticed certain things and misunderstood what was rendered by the computerized system. In term of skills, what was necessary was the ability to construct a representation of the state of the machine based on the correct association of information read on the screens and physical phenomenon observed on the machine:

> In this context, the diagnosis was false and the problem was that the effect of trials and errors which could produce facts different from what the computerized system indicates." (Maintenance technician, expert on the K)

Moreover, he emphasized the fact that the task force, even while intending to work in a professional manner, reproduced habits that consisted in fast forwarding to solutions before properly performing diagnostic tests:

> More fundamentally, one of the main problems here, in this case and in this shop, is that when facing a problem, people offer solutions but didn't know how to do the intermediate work of analysis…

The former maintenance engineer confirmed this when interviewed:

> When the K doesn't work there are many managers who have ideas but they actually don't know how it works…we had an operating method in which we had specific reliable procedures for tests with nitrogen. Using nitrogen sensors, we tried to find the leaks… One day, we had water in the K. It was catastrophic! Actually, it was the result of some operators' oversight. But the deputy plant manager thought that the K was leaky. We (maintenance) knew that this was not the case but we spent the whole weekend making a heat exchanger, because the management of the shop was sure of its diagnosis.

According to both actors it is due to the fact that production managers didn't recognise the specific skills of maintenance and when confronting serious problems opted to consult external specialists rather than having confidence in the local maintenance specialists.

> I could give you an example, but there are so many. Some years ago, before the K became reliable, we had problems maintaining a constant quantity of steam. The deputy plant manager insisted on installing a steam "super heater". I knew and said at the time that this was not the correct solution; moreover, it will have consequences for the rest of the machine. But they insisted. That's why I asked someone at SP to explain, with strong technical arguments that steam functions with constant flow but not by heating. So, they accepted that it was not a good solution. (Maintenance technician, expert on the K)

However, they didn't pay specific attention to an important statement of the K maker: one of the problems to diagnose the failure was the successive modifications and adaptations made on this equipment.

These two points show that social repair was needed. There was opposition between local maintenance specialists and production managers, which reflected conflicts between local maintenance technicians and operators because of the latters' practice of neglecting equipment. Thus, I now turn to the aspects of the diagnosis and repair work that explicitly concerned social structures and practices.

### 4.2. Repairing Organisation but not Social Practices

The diagnosis concerned not only material causes but also practices that led to the fatal fix. Sociological studies on compliance with procedures and rules have demonstrated that non-compliance can be used to compensate poor organizational design (Bourrier 2003): organisational lacunae, improper working conditions (Terssac 1992). In the present case study, because of successive reorganisations, maintenance became opaque for internal maintenance specialists as well as for all actors working in the shop, even managers.

On this part of the diagnosis opinions diverged, specifically between technicians and managers. The maintenance technician explained his colleague's fix in terms of an attempt to repair a dysfunction:

> It is an untraceable modification, unofficial. But there were visible traces, insulation installed to make an isolation box. Someone who knew the piece of equipment well would have seen it [...] In fact, this is a vacuum management system using ejectors. The double steam envelope that covers the ejector leaked. My colleague stepped in and put a tracer on the steam envelope to isolate it. But it created condensation in the ejector that made it impossible to obtain the vacuum level required. (Maintenance technician, expert on the K)

At the same time he outlined developments in maintenance organisation that led to the loss of repair memory and organisational choices that made work difficult.

On the other hand, the maintenance engineer, the production engineer and the manufacturing director explained it in terms of personal misconduct, due to a lack of skill and knowledge and non-compliance with procedures. In shop meetings, in informal reports addressed to the operator teams and in interviews these actors never cited the name of the technician who performed the faulty modification. In their statements, they used the expression "the person who made the modification" to refer to the technician in question:

> There was a change that the person found to be not significant. This was a problem of reflection and analysis. The person had not seen the scope of the modification, since the modification was not traced, we have not been able to identify ... This demonstrates the usefulness of the procedure and in particular modification procedures; the person who made the change did not say anything because they did not consider it as important. (Maintenance engineer, head of the maintenance department, task force)

However, despite his position in the hierarchy, the Maintenance engineer never explicitly pointed to the responsibility of the technician and did not take any steps to sanction the technician.

He joined the two other members of the task force and the manufacturing director to insist on the lack of resources for managing the shop:

> This has revealed a deep problem: the state of the shop. It was really a pity that nobody knew how to proceed when facing such a problem... No Proceed engineer dedicated to daily production. The new production engineer who is facing an incredible number of problems, and who doesn't master the proceeds or the general situation... This shop is disorganised, unable to call for help. (Plant processes expert, task force)

Yet, they did not question that these organisational choices were ones for management – their peers and themselves. They did not try to elicit the working conditions of the local maintenance technicians, which would be to understand working practices as linked to structures and equipment transformations through mundane maintenance, successive adaptations and improvements. However, observations revealed that maintenance technicians had to cope with a workplace where non-compliance was a widespread and institutionalized practice. Because of the fragmentation of maintenance and repair, they had to work with incomplete information on the state of equipment. Due to poor internal resources, they sometimes overcame failures and breakdowns on their own, as in the case of the technician who set up the fatal fix. However, this reality remained unknown to the maintenance and production managers because of the increasing opacity of maintenance and repair work through successive reorganisations and successive equipment evolutions.

Moreover, members of the task force did not look for organisational explanations for the difficulties they faced during the diagnosis. As a result they asked of and obtained a strengthening of the maintenance hierarchy in the shop, without modifying concrete resources for local technicians. They considered hierarchical forms of organisation as the solution for repairing failures due to the previous matrix form. By reinforcing the hierarchical structure of the shop, they denied any form of power related to skills and the necessity for maintenance specialists – engineer and technicians themselves – to benefit from the resources of an "interface-actor" (Francfort et al. 1995) in the organization: between workers and equipment, between subcontractors and production, able to understand, document and record equipment evolutions and transformations. They decidedly lost the prerogative of the "marginal-secant" (Crozier and Friedberg 1997), unable to "reach a whole series of possible resources, especially relations with the environment ... the control of information and the allocation of resources but also membership in an informal network, to control rules and cultural enhancement within the company" (Francfort et al. 1995, 164). They underestimate the consequences of the non-stability of technologies, more specifically, the unpredictable interactions between fixes, which, as Perrow outlined it, threaten the system.

At this point, one question remains: why, despite difficulties in performing the diagnosis, were members of the task force reluctant to bring skilled maintenance specialists into the process? To explore this question, I will now turn to an analysis of how managers engaged in the task force tried to combine the repair of the breakdown with the replacement of the computer system to repair their shop. This will also help us to deepen our understanding of the manager's diagnosis in terms of individual fault.

## 4.3. Contradictory Repairs

Why not ask for specialists' help in the shop and at the plant? One might imagine that it was due to the "silos" between production shops and others departments. However, the pressure to re-start production was at a climax. Paradoxically, according to the maintenance director, the public character of the breakdown made it difficult to seek external assistance:

> The breakdown has become the business of the plant; when this shop coughs, the plant catches a cold! But at the same time, the public nature of the problem makes it difficult to ask for external assistant and bring in people with real skills. (Maintenance Engineer, Head of the Maintenance Department)

At issue here was the credibility of the management of the shop, concerning both production and maintenance.

The stakes for the maintenance director were to demonstrate his expertise and show operators and production managers that internal maintenance was still useful and had sufficient skills to resolve major breakdowns. Even though they were forced to work at a distance from the equipment for many years, except during scheduled maintenance shutdowns. Moreover, the breakdown was an opportunity for the maintenance director to develop strong, on-going relationships with production managers, especially with the production engineer and his deputy. With their support, he gained a position from which negotiate resources for maintenance. Because he participated in the resolution of the shop's difficult situation, he supported the new production engineer in his delicate attempt to establish his authority.

In return, the production manager and his deputy supported him; the deputy plant manager knew exactly who had the skills to solve the problem but, like the managers, he wanted to deal with it without external assistance. At the same time, his desire to protect operator morale participated in restoring the credibility of maintenance and production management. He tried to protect the task force from the operators, who saw the task force at work without knowing exactly the issues they were facing. This was successful during the diagnostic phase.

As the manufacturing director explained, the presence of the task force and its members' efforts to demonstrate their involvement in solving the problem were vital to repairing the relationships between operator teams and management.

> I suppose that people react to problems according to your level of involvement. If you show that you have an interest… With our teams, people are waiting for help. They know that you are in a position in the hierarchy and that you can act. Not taking that into account would be a lack of consideration. The boss is not only the one who gets the most out of the situation. He is the one who gets

> the job done. It takes time and effort. I consider it an important part of the job. (Manufacturing director)
>
> People are aware of the weaknesses of the shop; they expect a sign from us to show the importance that we give to this shop. (Manufacturing director)

The production manager and his deputy could explain their reluctance to call in external assistance: this breakdown and the replacement of the computer system were opportunities to recover authority over independent and unpredictable teams. The repair was an opportunity to demonstrate operator skills and credibility, and, consequently, to reset the shop's working atmosphere and relationships. The reorganisation of the plant management team established the production engineers as powerful actors because able to negotiate and obtain resources from the plant's upper management. In addition, for the recently hired production engineer, dealing with problems was a way to demonstrate to his supervisors that he was able to control and manage shop activities and cope in a competitive environment. Finally, they used the repair of this device to repair their shop and its reputation within the plant. They considered the "K" as a machine which complexity made its repair delicate. However, they didn't understand that the successive small fixes, not systematically documented and recorded constrained the breakdown's diagnosis and repair.

In light of these interrelated strategies the diagnosis of the faulty fix as the consequence of individual error can be better understood. First, this explanation tracks that used to justify the characteristics of the new computer system: operators reluctant to follow procedures. This argument was at the centre of the specifications of the system and linked to the necessity to restore authority. This perspective opposed the rationalisation of the actions of unpredictable and unmanageable operators to the regulation and reliability of actions imposed though the new system. In the case of the fix performed on the "K", the only way to control human error was to reinforce control through the presence of a maintenance manager. Finally, the individual worker and collective action are represented as the unmanageable elements of the systems that need to be fixed with technical systems linked to hierarchical authority.

In the end, the maintenance engineer, the shop manager and the deputy plant manager succeeded. They obtained permanent resources following the diagnosis of the shop's situation that they reported to the plant management: the shop's management was reorganised into a "plant management team" composed of a production engineer, deputy plant manager and a new maintenance engineer. This reorganisation aimed to increase communication between maintenance and production, and make clearer the lines of reporting for issues coming out of the respective departments.

However, this reorganisation was focused on the control of production teams and their relationship to equipment issues. Except for this new maintenance engineer, the organisation of repair and maintenance activities remained the same as before: the allocation of material, human and economic resources, the distribution of tasks and responsibilities between local maintenance technicians and subcontractors, the contract terms with subcontractors, the control of routine repairs — all were maintained unchanged.

## 5. Conclusion

In this article, I have studied in depth a specific empirical context to show how managers seized on the repair of a complex machine in a sociotechnical industrial system to serve their strategy, which aimed at restoring their authority over production operator teams. Ultimately, this local repair participated in a more large strategy oriented toward the reparation of the material and social orders in the shop. The repair of the "beast of grief" was part of a fragmented maintenance, distributed among actors and collectives of workers. It consisted in a cautious and delicate intervention that required precise skills, but also the ability to deal with the opacity of maintenance in the workplace. This repair can be described as a process by which "technical constraints, social power, on-going actions and interpretations mingle to create social order" (Barley 1988, 52).

To conclude this article, I want to discuss some theoretical and methodological issues raised by this study of a major breakdown, within a framework that brings together the sociology of work, organization studies and STS. In the case study presented here, I adopted an intermediate perspective between workplace repair and infrastructure repair. I considered organisation, the dynamics of social relations and practices, and the history of the shop so as to understand how the repair of a complex device, which constitutes a small part of a socio-technical system, is used to repair the shop's material order and its organisation.

As emerged from the presentation of empirical data, the shop existence and its identity were at stake. However, the actors who performed the diagnosis and repair were not specialists. As a result, the study of their work revealed the specificities of machine repair in this kind of socio-technical system and the state of the relationships in the workplace. Because of these features, the case and its study allows a discussion with the sociology of socio-technical repairs initiated by Sims and Henke (2012) on three main points. First, the strategy of weapons specialists to restore their credibility was to embed their tacit knowledge in the new socio-technical context. In the case study, discussed here, actors considered the new computerized system as a support for organisational change. When facing the K's breakdown, they tried to embed it in the IT outages and equipment failures.. They considered that diagnosing and repairing the breakdown would help them to overcome the issue of their credibility towards operators' teams. However, this strategy that consisted in the combination of technical and organisational repair failed. Actually, these categories of repairs have appeared contradictory depending on their scope and their nature. 1) As Perrow (1983) has noticed for other cases, small and bigger technical repairs on the same equipment appeared to be conflicting:, small fixes performed on the defective equipment introduced constraints to the breakdown diagnosis and the repair, because of their unexpected consequences and their invisibility for non-experts; 2) technical and organisational repairs were not complementary. Actors engaged in the task force to repair the shop's organization paid attention to technical repair. However, their focus on the shop's organisation and ultimately on its reputation within the plant threatened the diagnosis and the repair of the defective equipment. Actually, they understood the breakdown according to the framework they derived from their main objective: they analysed it in terms of individual errors, procedures non-compliance, that would call for control over operators' teams and reinforcement of hierarchies.

Third, Sims and Henke (2012) presented tacit knowledge as the main resource for nuclear weapons scientists' strategy. In this paper, I highlight how the issue related to tacit knowledge is linked to opacity of maintenance in the workplace: local maintenance specialists knowledge – experts of the "K" device – were not enough articulated, because of successive reorganisations of mundane maintenance and repair and because of broken relationships in the workplace and within the plant. These weaknesses were strengthened by managers' acceptation of technologies as stabilized objects, with strong boundaries they could seize on to solve higher-level issues. Their choices revealed that they were trapped in a "technological fix" strategy: they tried to repair broken relationships, organisational failures with the new computerized system. However, they neither "used the power of technology in order to solve problems that are non-technological in nature" (Volti 1995, 23), nor they tried to simplify problems that are intrinsically social and technological and too complex to be solved as a whole (Weinberg 1967). The case of this breakdown revealed an intermediate situation where technological and organisational repair were only partially combined. As a result, studies on the repair of sociotechnical systems could be deepened. First, the "sociotechnical repair" category could be refined with the notion of "technological fix" and its discussions (see for example Rosner 2004; Scott 2011). Second, we could consider maintenance as an on-going process of work (cf. Barley 1988 cited above) on the categories of repair that actors try to combine, and on the potential conflicting issues between them. This offers the opportunity to precise what "socio-technical" means in the case of repair and the links between repairs practices and maintenance issues in the workplace.

I insist here on three additional steps in developing a sociology of repair that brings together the sociology of work and STS.

First, from a methodological perspective, this article is an attempt to investigate an intermediate level, halfway between studies in ethnomethodology and analyses of macro scale structures. However, this can be refined (see for example Grossetti 2011). At this "meso" level lays the difficulty of understanding human actions in the construction and the conflicting dynamics of social order. Because of the micro situations they mainly analyse, ethnomethodological studies tend to overshadow structural issues in order to explore material properties and relationships to things. Therefore, I considered organisation studies on technological change. This perspective allowed me to understand how actors considered and combined the material components and social practices and structures they repaired. Moreover, it drew attention to the fact that these combinations were not only consequences of smooth negotiations and machine properties but depended on organisational structures, social practices and power. The maintenance of material and social orders depended on local individual and collective strategies that were due to actors negotiating their participation in organisation. This participation is not systematic and depends, among other things, on the social context and on history. For this reason, it would be useful to consider historical dimensions in a more extensive manner than I was able to in this study. I presented only the elements of the history of the shop that highlighted the breakdown and the maintenance practices in the shop. One problem here is that it focuses on the elements that are important to the situation studied and downplays others. For example, it would be interesting to consider, while studying repair and maintenance of industrial processes, the history of collective resistance and mobilizations, major breakdowns and accidents. This attention to history would deepen our understanding of the way actors' actions are linked to their intentions, to their adhesion to the workplace productive order. Moreover, we would be able to specify the underlying social dynamics of the workplace order.

Second, I focused here on the work of maintenance technicians, with no attention to the work of subcontractors. It would be interesting to explore their relationship to equipment and their participation in the material and social order as intermittent actors. This orientation would enrich the notion of the workplace so as to deepen the analysis of the dynamics of construction of collective skills and distributed skills.

Finally, this repair of a major breakdown in a socio-technical system is a good case study for extending the "sociology of repair" initiated by Henke (Henke 2000) and extending it to higher levels including power issues. It offers insights for STS researchers who study scientific activities in organised workplaces as well as for sociologists of work who are interested in analysing the links between technical work and social order. It opens perspectives for developing case studies on repair, to complete the results of organisation studies on technological change, and understanding "why people do the things they do with technology and why organizations and practices acquire the forms they acquire" (Leonardi and Barley 2008, 172). Further theoretical discussions about theories of action including actor intention, and the ways technology and organisations shape one another, are needed to develop a complex frame of analysis. This would stimulate further discussion of material and social determinism and voluntarism, along the lines initiated by Leonardi and Barley (Leonardi and Barley 2008).

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