

## INTRODUCTION

The purpose of this report is an in-depth study of the possible causes of the fact that two workers who normally work with the same machine and in the same work post present the same type of injury in both wrists.

In general, oosteotendinitis of the hand in the workplace is caused by repetitive movements with micro-traumatism or forced postures (**González 97 and Zwart 97**).

Although not the most frequent, said pathology is also caused by brusque movements that bring about twisting of the wrist and/or pressure on the palm of the hand.

This pathology has been described in very different terms: “Cumulative trauma disorders”, (USA); “Occupational overuse syndrome”, (Australia); “Repetitive strain injuries”, (Great Britain), “Injuries attributable to repetitive work”(Canada), “Muscular-skeletal alterations” or “Overuse pathology”(France) (**Iselin**). Included in oosteotendinitis pathologies are tendonitis, tenosynovitis, bursitis, epicondylitis and the most frequent, carpal tunnel syndrome. It is estimated that 10% of the population shows a high risk of suffering from this (**Valls**).

We must not forget the incidence of this type of industrial injury, particularly in industrialised countries such as USA, where 47% of industrial injuries are Carpal Tunnel Syndromes (**Schwartz 1992**), and their serious effect on companies’ productivity due to high level of absenteeism and the high costs associated with the illness and its treatment.

For this work, an exhaustive review of bibliography was carried out to know the possible causes of this illness. Once the causes were known and the appropriate study of the work position was carried out reviewing the Technical Work Instructions, observing the manner in which the work was performed, and analysing the same, the different aetiologies were gradually ruled out until we discovered what could be considered as the most probable causes that spark off this injury in workers.

Having discovered the causes and possible origin of the injuries, appropriate measures were taken to minimize the motives of the same and an analysis was carried out to check the measures adopted.

## **BACKGROUND**

In 1997, there were two cases of oosteotendinitis of the carpal tunnel in workers normally operating this machine.

In both cases, on exploration of the two wrists, a positive Phalen sign was observed. A slight neuropathy of the median nerve as it passed through the carpal tunnel was observed in the electro-myogram, and the magnetic resonance showed a thickening of the peritendinose sheath at carpal tunnel level.

These injuries gave rise to temporary work incapacity that seriously altered the production process. Because of the seriousness of the matter, both from a medical and labour point of view, on the initiative of the Prevention Service and in collaboration with the installation's technicians, a study was commenced on the possible causes of the said pathology.

## **CARPAL TUNNEL SYNDROME (CTS)**

CTS appears to be caused more by repetition level than level of force. Cumulative traumatic illnesses of industrial origin include work that requires the tasks of cutting, sanding, typing, polishing, hammering, jobs involving vibratory machinery/tools, assembly work and others (**Menárguez 96**).

## AETIOLOGY

Carpal Tunnel Syndrome can be caused by multiple factors: any cause that creates a conflict of space can produce compression of the nerve creating an injury, which if it becomes chronic, seriously affects the nerve, causing irreversible atrophy.

Among these factors are those of a mechanical nature due to functional demands on the wrist and fingers during activity at or outside work.

Included in this group are the repetitive flex-extension movements of the wrist and fingers, forced and maintained postures of the wrist, tightness of hold, regular use of vibratory tools and repetitive micro-traumatism, prolonged leaning on the base of the palm of the hand.

Repetitive micro-traumatism is a frequent source of hand injuries and has given rise to exhaustive studies in the workplace, determining certain risk factors (**Solé, M.D. 93**) :

- ◆ Maintenance of forced postures of the wrist or shoulders.
- ◆ Application of excessive manual force.
- ◆ Very repetitive work cycles with rapid movements of small groups of muscles or tendons: as in the case of the Carpal Tunnel Syndromes that motivated the request for action by the Prevention Service and the improvement proposals contained in this study.
- ◆ Insufficient rest periods.

The most frequent causes of industrial Carpal Tunnel Syndrome are tendonitis and tenosynovitis of the flexors of the fingers (**MOORE 95**): the flexor tendons or their sheaths become inflamed, occupying more space in the tunnel and thus compressing the nerve (due to excessive friction - in frequency, intensity or lack of physiological recuperation - as it passes through the carpal tunnel). This happens with repeated micro-traumatism, cumulative traumatism when moving the fingers or forced wrist postures (**HALES 92, POULET 84, ROQUELAURE 96**).

Analysis of the mechanical factors described underlines the greater tendency of Carpal Tunnel Syndrome being observed in professions requiring repetitive hand gestures,

especially flex-extension of the wrist, a situation that worsens when these gestures are combined with tasks involving force, gripping and extreme postures (**BARON 92, BOSTRÖM 91, SAFETY MANUAL N°23**).

**The median nerve may be injured by a double mechanism:**

- 1) Mechanical deformity produced by compression.
- 2) *Alteration of the blood flow. The obstruction of circulation in the return vein produces intra-fascicular oedema, contributing to an increase in pressure on the nervous fibre.*

Compression of the nerve may produce functional changes, such as abnormal excitability or fibre blockage and structural changes such as demyelination and axonal degeneration (**Jeng O.J. 94**).

## **DESCRIPTION OF THE JOB POSITION.**

The automatic tooth welding machine, more commonly known as Bihler, is a machine with an embossed hoop on each surface from which a PVC band progressively makes the stamps, folds, welds and necessary checks, by means of placing a bridge of chrome-nickel wire to make the so called, “tooth combs”, which, after quality control both of combs and teeth, are sent to the fuse head manufacturing process where a layer of explosive is added to the teeth. From then on, they are called fuse heads, the elements responsible for initiating an electric detonator.

The work carried out by the operator consists of switching on the welding machine and the computer. He should also position the hoop bobbin and wire corresponding to the type of teeth to be made.

Once the machine has started, the operator should control any incidents that occur during the process, which may include the following:

- Failure in the wire welding detector
- Considerable difference in the width of the “prongs” of the teeth.
- Off-centre combs.
- High or low weld resistance.
- Burnt wire.
- Opening of the teeth

In the event of an incident, the worker is advised by means of luminous and sonorous signals on the control panel, indicating the motive of the incident.

This machine produces around 108.000 good teeth per working day, at a frequency of 300 teeth per minute.

20 teeth make up a comb.

The operator removes the production from the machine and deposits it in a small container every 5 minutes, which involves around 75 combs every five minutes.

Before the combs are stored, they must pass quality control consisting of the following stages:

- Selection or classification of combs. This is a visual control of the combs that are then classified according to the width of the PVC band.
- Visual control of the correct placement of wire and correct welding to the tooth. This control is carried out by checking the welds of the teeth with a 10-magnification microscope, checking the correct proportion of the “prongs” of the teeth and that they are centred in the comb.
- Cutting of teeth. This control phase consists of cutting and separating the teeth from the comb using pincers.
- Measuring resistance. Resistance of the teeth is measured by an ohmmeter, results being registered in a miniprocessor.

This quality control should be made every 15 minutes on a comb by cutting two teeth. If these pass the control, the combs made by the machine in this period are placed on trays perpendicularly aligned with the bottom of the tray.

A fast and precise use of the fingers of both hands is required in this operation, which may be compared to the movement of a typist. These trays are then stored and sent to the fuse head manufacturing process.

This control is also carried out each time the hoop bobbin is changed, which is more or less every two hours.

### **DESCRIPTION OF THE WORK SPACE**

This work post is located in a warehouse where other metal work is carried out.

The Bihler machine occupies a rectangular space 160 cm. by 130 cm. and a height of 180 cm.

The welding computer and the machine computer are perpendicular to the machine and occupy an area of 170 cm. by 57 cm. and a height of 180 cm. The machine controls are at a height of between 80 and 100 cm. above the floor and beside the computers.

The worktable on which the quality control of combs and teeth is carried out is located in parallel to the Bihler machine, at a distance of 170 cm. and perpendicular to the computer controls and separated from it by a corridor of 90 cm.

The worktable measurements are 220 cm. by 70 cm. with a height of 82cm..

On this table there are:

- ⇒ A 10-magnification microscope with a height of 36 cm. The height of the platform on which the combs are placed is 18 cm.
- ⇒ The Ohmmeter with a height of 36 cm., the height of the slot where the tooth is placed being 9 cm. and the height of the switch 2.5 cm., all above the height of the table.
- ⇒ The trays where the combs are placed for storage. These trays are 41.5 by 32 cm. in size with a depth of 2.5 cm., and are divided into six compartments measuring 12.5 by 14.5 cm.
- ⇒ 415 combs are placed on each tray that is to say, 8300 teeth.
- ⇒ The cutting pincers and the microprocessor for the ohmmeter are also on the table.

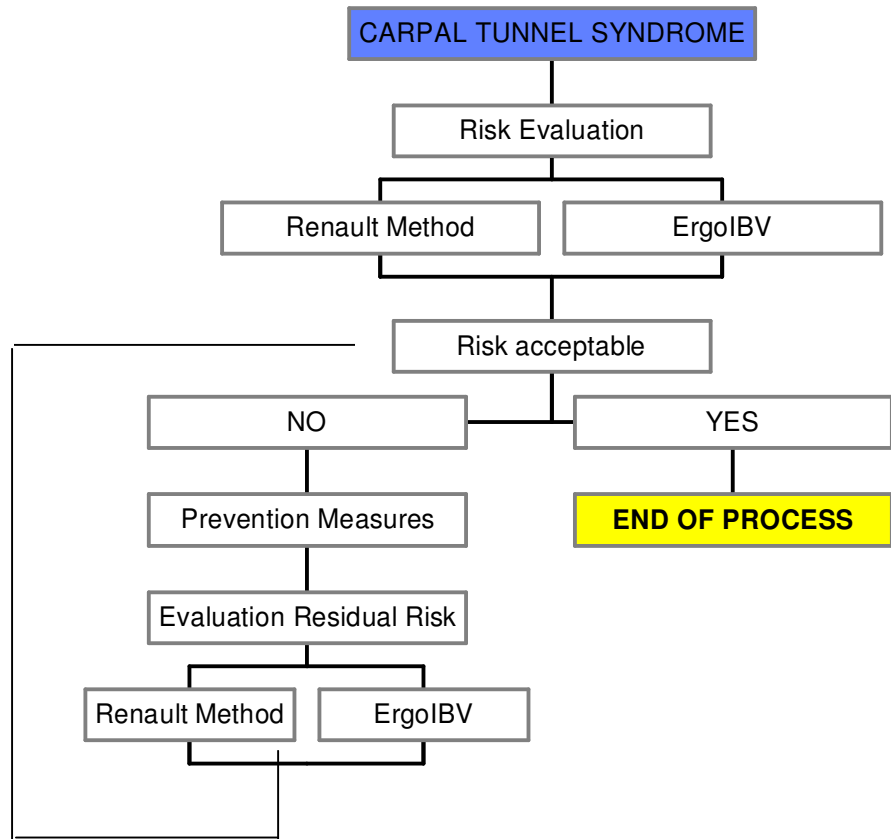
The operator has an adjustable seat with a metal structure and four legs without wheels.

The seat and backrest are of wood, the latter is adjustable to posture and the upper edge is at a height of 32 cm. from the seat.

## **ERGONOMIC ANALYSIS**

### ***EVALUATION METHOD***

Diagram of the methodology used:



To study this work post, the Renault Method and the Method of the Valencia Institute of Biomechanics (ERGO-IBV) were used, the latter being most selective for the study of work posts with micro-traumatism or repetitive movements.

## DESCRIPTION OF THE RENAULT METHOD

The Renault method is designed with four priority objectives:

- \* Improve safety and environment.
- \* Reduce the physical and nervous workload.
- \* Reduce troubles arising from repetitive work or production line.
- \* Create a growing proportion of work positions with higher interest level.

This method allows technicians and specialists in working conditions to evaluate the main drawbacks of existing situations, as well as those being prepared. With these evaluations, the necessary corrections can be made or different technical solutions can be chosen that better respond to the objectives of the working conditions, taking into account the technical and financial constraints.

The application of the Renault method includes eight factors that are evaluated according to criteria, plus another four preliminary criteria that take into account the global conception of the post.

Description of the factors and the conception of the post.

- The conception of the post is evaluated according to four physical characteristics that check the correct adaptation of the post to the average worker. For this, the height-distance of the work plane, supply-evacuation of parts, space-accessibility of the work position and controls and signals, are assessed.
- Safety factor.** This factor evaluates the danger and probability of risk according to the nature of the work and the materials employed.
- Ergonomic factors.** Three factors are taken into account:
  - ✓ Physical surroundings. The surroundings of a sector or work post are characterized by a group of physical elements. Each criterion may be the cause of permanent or temporary injury to the worker and may progressively attack the integrity of his faculties. These alterations may be temporary or irreversible.

- ✓ Physical workload. Three series of criteria should be considered to evaluate the physical load of a work post. They permit measurement of the static postural load, the dynamic workload and the maintenance load. The physical load is the result of the three partial loads thus established.
- ✓ Nervous workload. The nervous workload is understood to be the combined requests experienced by the nervous system when undertaking a task. The overload of the nervous system tends to create alterations in the worker (exhaustion). The nervous load is determined by two criteria. One is the nervous load due to mental operations and the other is the nervous load due to level of attention.
- ☑ **Psychological and sociological factors**. The following factors are taken into consideration: Autonomy, Relations, Repetitiveness and Content of the work.
  - ✓ Autonomy. Is the power of the worker or group of workers to modify in time the rhythm of work or to abandon the work post when he wants without disturbing production in any way.
  - ✓ Relations. Relations depend on the possibilities of interpersonal communications during the period of work, tending to favour contacts, reduce isolation of the worker in his post, or to permit execution of a job as a group.
  - ✓ Repetitiveness/monotony. Activities with a short cycle entail great repetitiveness of identical movements. For the worker, this involves an automation of gestures that provokes fatigue and a sense of monotony in the work.
  - ✓ Work content. The content indicates to what measure an operator's work calls for use of his potential aptitudes, involves responsibility and arouses his interest.

These are complex factors both in their definition and for the worker in the job. However, the evaluation criteria are deliberately chosen in a simple and precise way to make it possible to arrive at an operative method that is easily useable by all technicians with adequate training.

***Meaning of the levels:***

Each criterion has five levels of satisfaction:

- 5 = Very poor or very dangerous. Priority improvement needed.

- 4 = Poor or dangerous. Needs improvement.
- 3 = Acceptable. Improve if possible.
- 2 = Satisfactory.
- 1 = Very satisfactory.

***Factors and criteria***

<b>CONCEPTION OF POST</b>			Height-Distance	1
			Supply-Evacuation	2
			Agglomeration - Accessibility	3
			Controls-Signals	4
<b>SAFETY FACTOR</b>		<b>A</b>	Safety	5
<b>ERGONOMIC FACTORS</b>	<b>PHYSICAL ENVIRONMENT</b>	<b>B</b>	Thermal environment	6
			Sound environment	7
		Artificial lighting	8	
		Vibrations	9	
		Atmospheric hygiene	10	
		Appearance of post	11	
	<b>PHYSICAL LOAD</b>	<b>C</b>	Main posture	12
			Most unfavourable posture	13
			Work effort	14
	<b>NERVOUS LOAD</b>	<b>D</b>	Working posture	15
			Maintenance effort	16
			Maintenance posture	17
			Mental operations	18
			Level of attention	19
<b>PSYCHOLOGICAL &amp; SOCIOLOGICAL FACTORS</b>	<b>AUTONOMY</b>	<b>E</b>	Individual autonomy	20
			Group autonomy	21
	<b>RELATIONS</b>	<b>F</b>	Independent work relations	22
			Dependent work relations	23
	<b>REPETITIVENESS</b>	<b>G</b>	Repetitiveness of cycle	24
	<b>WORK</b>		Potential	25
	<b>CONTENT</b>	<b>H</b>	Responsibility	26
			Interest in work	27

***Work cycle***

The work cycled studied was the quality control and storage of the combs in trays, which in summary consists of:

- ◆ removing the combs from the container in the machine

- ◆ selecting the combs
- ◆ visual control
- ◆ cutting the teeth
- ◆ measuring resistance
- ◆ introducing and placing the checked lot on the tray

### **I.B.V. METHOD**

A method devised by the Institute of Biomechanics, Valencia, in 1996.

This is a simple method of risk assessment for repetitive tasks involving the upper limbs and calculates the risk level based on objective measurements of the exposure factors.

It permits evaluation of risk in the neck-shoulder and hand-wrist areas independently and is based on data obtained in a field study.

The method is based on the calculation of the worker's average exposure to the different risk factors to which he is submitted in his work throughout the day. It calculates the risk associated with the job as a whole, related to a specific post or with the group of posts in which he carries out his activity.

To apply the method, it is therefore necessary to gather information on the different tasks undertaken by the worker and their duration, as well as to code the work postures, effort levels and muscular activity in each task.

#### ***Meaning of the risk levels:***

- \* Risk level I: ergonomically acceptable work situations
- \* Risk level II: situations that could be improved but do not require immediate action

- \* Risk level III: involves carrying out modifications in the design of the post or in the requirements of the tasks analysed
- \* Risk level IV: priority ergonomic intervention required

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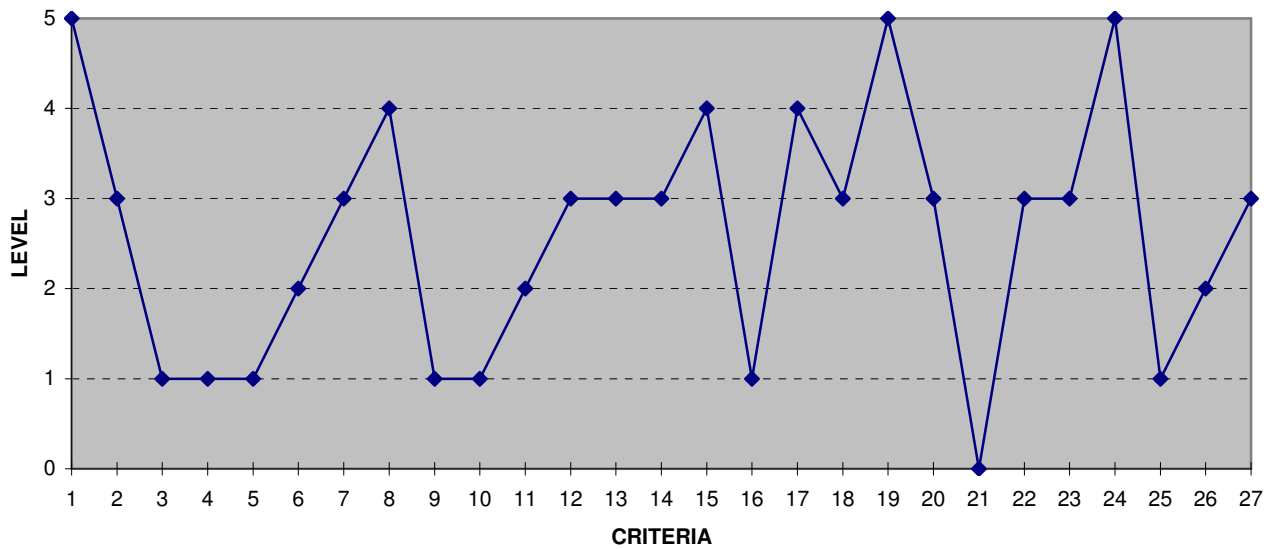
### **INTERVIEWS**

No less important than the above-mentioned methods was the collaboration of the operators, and their suggestions and contributions that were gathered during interviews held as a result of the request. It is true that this was not a controlled or validated survey, nor just one interview. The work method adopted with the operators was that of systematic interviews as a whole as necessary, or every time an innovation, suggestion or improvement proposal made it necessary.

### **RESULTS**

Renault Method:

### BIHLER MACHINE PROFILE



#### ***COMMENTS:***

#### **Conception of the post.**

According to the Renault method, in the conception of the work post, two unfavourable criteria, 1 and 2, were observed.

Criterion 1 evaluates height-distance.

The worker carries out his task sitting on an adjustable stool to control the teeth on a table 82 cm from the floor, and standing up 12 times per hour. Taking into account that the optimum height of the adjustable stool is 430 mm. and adding to this 350 mm, the height of the support, i.e. the table, is more than 780 mm. According to the method, this is a very unfavourable height and therefore evaluated at risk level 5.

Criterion 2, supply and evacuation of parts, obtains level 3 as a distance of 1700 mm has to be covered every five minutes and the combs have to be placed at a height of 820 mm. This situation is considered acceptable and for improvement if possible.

#### ***Physical environment factor.***

The noise at the control panel was measured, registering a value of 82.5 dB(A).

Lighting at the machine and the table was 300 Luxes.

Temperature and humidity were 19° C and 33% respectively.

There were no vibrations or chemical contaminants in the workspace atmosphere.

According to these readings, the values assigned to the criteria were:

Criterion 6 (thermal atmosphere) : Satisfactory = 2.

Criterion 7 (sound atmosphere) : Acceptable, but continuous noise to be improved = 3.

Criterion 8 (artificial lighting): level 4 assigned since it was considered that lighting level in Lux (300) was below post requirements. This is therefore a poor situation that requires improvements.

### ***Physical load factor***

In the criterion for static posture load, the main posture or criterion 12, was evaluated at level 3, taking into account that this is the sitting posture with the trunk bent forward for 80% of the day.

In the most unfavourable posture, or criterion 13, the valuation is also 3 as some work is carried out standing up and slightly bent for 10-20% of the day. In summary, it is considered acceptable and to be improved if possible.

The dynamic workload is the resultant of criteria 14 and 15. Criterion 14 or effort used to transform the product was scored 3, considering the effort used to cut the teeth of the comb with the pincers and the time dedicated to such task.

Criterion 15 or posture during the effort obtained value 4, since the frequency of cuts is 180 per hour in a sitting position with the trunk slightly bent forward. This is consequently a poor situation and requires improvement.

Criterion 17 or maintenance posture was given level 4 due to the frequency of repetition, 180 times per hour. It therefore receives the same valuation as criterion 15.

### ***Nervous load factor***

Criterion 18 or nervous load due to mental operations obtains a value of three because of the density of mental operations.

Criterion 19 or nervous load due to level of attention receives value 5 due to the duration of the attention, which is around 80%, and the precision of the work. Together with no. 1, this is the worst criterion described to now and needs priority improvement.

***Repetitiveness factor***

Criterion 24 or repetitiveness of cycle was evaluated in respect of the duration of the cycle, which in this case would be 2, but the internal repetitiveness, that is to say the high frequency of identical operations with a short duration during the cycle, aggravates this criterion. According to the method, this represents a total value 5, which classifies it as very poor and dangerous.

**I.B.V. METHOD**

The description of the task and analysis of the postures are described in Attachment I.

The results shown in these tables correspond to the risk levels detected for each of the activities independently.

***Selection of combs:***

Risk of trouble or injury	Short-term	Medium-term	Long-term
Neck	II	III	III
Wrist	IV	IV	IV

***Visual control of weld:***

Risk of trouble or injury	Short-term	Medium-term	Long-term
Neck	III	IV	IV
Wrist	III	III	III

***Tooth cutting:***

<b>Risk of trouble or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	II	III	III
Wrist	IV	IV	IV

***Resistance control:***

<b>Risk of trouble or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	III	III	III
Wrist	III	III	III

***Storage of teeth:***

<b>Risk of trouble or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	III	IV	IV
Wrist	IV	IV	IV

**Risk levels of global activity:**

<b>Risk of trouble or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	III	III	IV
Wrist	IV	IV	IV

According to the study of the task and analysis of the postures, the risks detected by this method indicate to us the high rate at which people who perform these tasks suffer injuries to the neck and wrists.

The problems or injuries to the neck may be due to flexing of the neck:

- ◆ when observing the wire and welds
- ◆ when cutting the teeth with the pincers
- ◆ when cutting the combs

The problems or injuries to the wrist may easily arise in:

- ◆ selecting the combs
- ◆ cutting the teeth with the pincers
- ◆ storage or folding of the combs

## **DISCUSSION**

Following the Renault method, the results obtained from the analysis of this work post show shortcomings in the design of the post, in the physical environment, the physical load, the nervous load and in the repetitiveness factor, as well as non-compliance with the Technical Work Instructions.

The high repetitiveness of the work cycle, which bibliography marks as the main cause of Cumulative Trauma Disorders, in our case industrial Carpal Tunnel Syndrome, was caused by non-compliance with the Technical Work Instructions of this machine. Thus, when the TWI indicated that the comb quality control should be carried out with a frequency of two teeth every 15 minutes, the cycle analysed revealed that such control was made with a frequency of 2.3 times per minute, i.e. the work cycle was less than thirty seconds.

Using the IBV- ERGO method, the existence of highly repetitive movements was confirmed, in addition to inadequate flex-extension and maintenance postures as well as insufficient rest periods to recovery, all these criteria being included in manual NIOSH 1989 to define the Carpal Tunnel Syndrome associated with work. (MARQUÉS 92)

As a result of the review of literature on CTS attributable to work, this illness may be summarized according to the NIOSH definition and the description made by other authors on the same:

## **NIOSH. CUMULATIVE TRAUMA DISORDERS**

**CUMULATIVE:** Injuries which develop gradually in periods of weeks, months or years, as a result of repetitive efforts on some part of the body. The cumulative concept is based on the theory that each repetition of an activity produces a trauma in the body tissues or joints.

**TRAUMA:** Trauma refers to a body injury caused by mechanical effort.

## **CUMULATIVE TRAUMA DISORDERS**

The production mechanism consists of a high repetition of movements by the hand and wrist. They are tasks that require very simple jobs to be carried out: take, push. A large number of workers have jobs with potential risks of suffering CTD.

One reason that makes the true incidence of CTD difficult to determine is that the pain and limitation of movement develops little by little, over months or years.

Tendons to flex the fingers, the median nerve and the blood vessels run through the carpal tunnel. Certain positions and movements may cause **CARPAL TUNNEL SYNDROME**.

Jobs that combine effort with a repetitive posture have a high risk.

The results obtained, interviews with workers and observations, confirmed:

- High repetitiveness due to non-compliance with the TWI (excess diligence).
- Excessive manual effort when cutting the teeth with the pincers, as well as sustained effort by small groups of muscles when operating the digital pincers.
- Forced wrist postures, with cubital deviation and rapid flex-extension movements, mainly when cutting the teeth and measuring the resistance of the teeth in the ohmmeter.

- Forced neck postures, as a result of the visual control when examining the combs, teeth, when cutting the teeth and folding the combs.

## **PREVENTIVE MEASURES**

## **RECOMMENDATIONS FOR RE-DESIGN OF WORK POST**

According to the job profile obtained by the Renault Method, a series of proposals was made to improve said post:

### **Conception of the work post.**

Given that the frequency of going to fetch the combs from the machine was over six times per hour, the recommendation was to place a worktable with a height of 1000 mm. This height was given to the table taking into account that to work standing up, the elbow-floor distance of both workers is 1010 mm. including shoes.

It was also advisable to replace the current stool by another that provides ideal support for outstretched legs, easy to stand up, supporting the spine with a straight back and allowing freedom of movement for the legs.

In addition, a worktable was designed, Attachment IV, according to the areas of Farley that permit introduction in the normal working areas of the elements usually used in quality control.

These modifications should permit that the criteria on height in relation to floor and distance in depth, pass to level 1.

The supply/evacuation would also improve, reducing the frequency of comb collection by means of a larger deposit than the existing one and by raising the height of the table to 1000 mm. For these reasons, the level would go from 3 to 1.

### ***Physical environment factor.***

To improve lighting, it is proposed to lower the height of the lights and clean their protections. With this modification, an improvement to 600 Luxes is achieved, placing us at level 2, and in addition complying with Attachment IV “Lighting in the work areas” of the Royal Decree 486/1997 of April 14<sup>th</sup>.

### ***Physical load factor.***

Static load posture: this also improves since with the change in height of the table and re-design of the work area and stool, allow the worker to carry out his job either standing up or sitting on the stool, so that the level for the main posture and the most unfavourable posture would be 2.

The criterion of dynamic workload would also improve if the pincers used to cut the teeth were replaced by another system that avoids effort by the hand as well as reducing the frequency of cuts according to the proposal to reduce the number of controls and thus of cuts going from 180 per hour to 24 per hour, with which the level would go to level 1.

The criteria for posture during the effort also improves since the fact that the worker can work standing up and the control of teeth is reduced to 24 per hour would place us at level 1.

### ***Nervous load factor.***

The criterion for level of attention will also improve as a consequence of the reduction in duration of the visual control of the teeth, which passes from level 4 to level 1, so that the level of attention would go from level 5 to level 3 since the work precision would not vary.

### ***Repetitiveness factor.***

This would diminish due to reduction in repetitiveness of the internal cycle on the one hand, that is to say the reduction in controls of teeth, and the increased capacity of the container for the combs on the other, the cycle for collecting the combs increasing to every 10 minutes instead of every five minutes. As a result the repetitiveness factor would be 2.5 since the duration of the cycle would be 1 to which 1.5 would have to be added as a result of the internal repetitiveness.

According to the recommendations made by the IBV-ERGO Method (Attachment II), a series of improvements or modifications was made in order to reduce risks detected by this method.

A series of changes was made on the comb and tooth control table and the tools used:

- The pincers used to cut the teeth were replaced by a pneumatic cutter actioned by a foot pedal.

This cutter was embedded in the table in such a way that the comb runs along a small rail and positions the tooth over the cutting area. This movement is made holding the comb in the left hand and holding the tooth to be cut with the thumb and index finger. The two wrists are supported by the palms on the table in a neutral position.

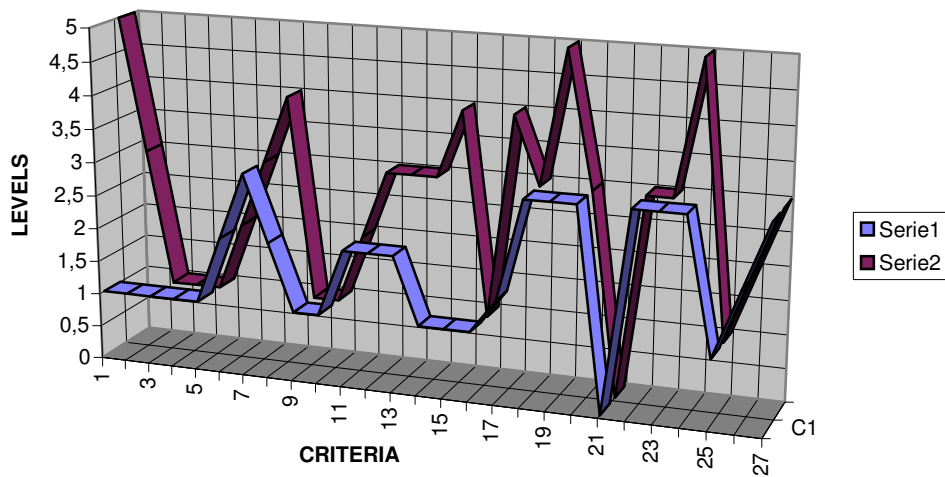
- The resistance of the tooth is measured by an ohmmeter, also embedded in the table and in line with the cutter, in such a way that the cut tooth, still held by the right hand in a neutral position, is placed in the ohmmeter, and the left hand actions a mouse located on the table pressing the left key to fix the tooth and the right key to take the resistance reading and send it to the microprocessor.
- The tooth storage trays were replaced by boxes 21x15x6 cm and inset 6 cm in the table in order to avoid flexing movements of the palm when placing the combs horizontally inside the box.
- On the other hand, the previous modifications and the microscope and microprocessor were adjusted to the normal working area developed by Farley.

## EVALUATION OF THE RESIDUAL RISK

As a consequence of the changes produced in the work post, according to the problems detected by the Renault Method and by IBV-ERGO, the work post was evaluated once again using these two methods, obtaining the following results.

### RENAULT profile

**PROFILE COMPARISON BEFORE & AFTER THE MODIFICATIONS**



*Series 1 after the modification*

*Series 2 before the modification*

Following the new evaluation, the results obtained in those criteria at levels 5, 4 and even 3 have improved.

✓ *Concept of the post.* All criteria are at level 1, so we are able to say that it is a very satisfactory post.

✓ *Ergonomic factors.* Lighting has improved moving from level 4 to level 2.

Physical load has improved significantly in all criteria passing from levels 3 and 4 to levels 2 and 1. That is to say, they have passed from acceptable levels in some cases and in others from dangerous or poor, such as maintenance posture, to very satisfactory or satisfactory levels.

Level of attention also improved from a poor to acceptable situation.

✓ *Psychological factors.* The worst of the criterion was that of repetitiveness which had a level 5. After the improvements, and in particular due to compliance with the Work Instructions, it went to level 3.

## **ERGO-IBV**

Task description and posture analysis of the risk following the modification of the task are described in Attachment III.

The results shown in these tables correspond to the risk levels detected for each of the activities independently.

### ***Selection of combs:***

<b>Risk of problems or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	II	II	II
Wrist	I	I	I

***Visual control of welds:***

<b>Risk of problems or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	III	IV	IV
Wrist	I	I	I

***Cutting of teeth:***

<b>Risk of problems or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	II	II	II
Wrist	I	I	I

***Resistance control:***

<b>Risk of problems or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	II	II	II
Wrist	I	I	I

***Storage of teeth:***

<b>Risk of problems or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	II	II	II
Wrist	I	I	I

***Risk levels of global activity:***

<b>Risk of problems or injury</b>	<b>Short-term</b>	<b>Medium-term</b>	<b>Long-term</b>
Neck	II	II	II
Wrist	I	I	I

Comparison between global risk level before and after the modifications:

<b>BEFORE MODIFICATIONS</b>			
<b>RISKS</b>	<b>Short-Term</b>	<b>Medium-Term</b>	<b>Long-Term</b>
NECK	III	III	IV
WRIST	IV	IV	IV
<b>AFTER MODIFICATIONS</b>			
<b>RISKS</b>	<b>Short-Term</b>	<b>Medium-Term</b>	<b>Long-Term</b>
NECK	II	II	II
WRIST	I	I	I

The modifications made in the work post, as well as the modification of the Technical Work Instructions, have visibly improved this post, since according to the RENAULT method from having very poor or dangerous qualification requiring priority action, it has passed to acceptable levels.

According to the IBV-ERGO method, it has been shown that from a risk level IV requiring high priority ergonomic intervention, it has passed to situations that can be improved but no immediate action is required, such as neck postures, and work situations that are ergonomically acceptable, such as incorrect wrist positions.

Having evaluated the residual risks and according to the evaluation systems used, we believe that we now have a work post that we can consider as acceptable.

This intervention in the post was due to the problem that had arisen. We hope that from now on we will be informed on projects in order to be able to act and propose improvements in design and thus avoid undesirable effects on the workers.

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## ATTACHMENT I

### **JOB REPORT: BIHLER**

◆ **Description of job:** List of activities associated with the task:

**1) SELECTION OF COMBS**

Exposure: 10% of task.

Repetitiveness of arm movements: 0 rep/min.

Repetitiveness of hand movements: 35 rep/min.

Main postures taken into account:

- *EXAMINATION OF COMBS* (100% of activity).

**2) VISUAL CONTROL OF WELDS**

Exposure: 10% of task.

Repetitiveness of arm movements: 7 rep/min.

Repetitiveness of hand movements: 7 rep/min.

Main postures taken into account:

- *PICKING UP COMB* (10.0% of activity).
- *PLACING OF COMB IN MICROSCOPE* (30.0% of activity).
- *OBSERVATION OF PRESENCE OF COMB AND WELD* (50.0% of activity).
- *REMOVAL OF COMB FROM MICROSCOPE* (10.0% of activity).

### 3) **CUTTING OF TEETH**

Exposure: 30% of task.

Repetitiveness of arm movements: 0 rep/min.

Repetitiveness of hand movements: 3 rep/min.

Main postures taken into account:

- *CUTTING OF TEETH WITH PINCERS* (100.0% of activity).

### 4) **RESISTANCE CONTROL**

Exposure: 40% of task.

Repetitiveness of arm movements: 3 rep/min.

Repetitiveness of hand movements: 3 rep/min.

Main postures taken into account:

- *PICKING-UP OF CUT TOOTH* (30.0% of activity).
- *PUTTING TOOTH IN OHMMETER* (40.0% of activity).
- *REMOVAL OF TOOTH* (30.0% of activity).

### 5) **STORAGE OF TEETH**

Exposure: 10% of task.

Repetitiveness of arm movements: 2 rep/min.

Repetitiveness of hand movements: 10 rep/min.

Main postures taken into account:

- *FOLDING OF COMBS* (100.0% of activity).

## **POSTURE ANALYSIS**

**1.- EXAMINATION OF COMBS: 100.0% of comb selection**

- ✓ **Arms:**  
Position between 20° extension and 20° flexion.
- ✓ **Wrists:**  
Extension or flexion greater than 15°.  
Radial or cubital deviation of the wrist.  
Intensity of effort: light task (less than 10% of maximum effort).
- ✓ **Neck:**  
Twisting of the neck.  
Flexion greater than 20°.

**2.- COLLECTION OF COMB: 10.0% of visual control of weld**

- ✓ **Arms:**  
Position between 20° extension and 20° flexion.
- ✓ **Wrists:**  
Extension or flexion between 0° and 15°.  
Radial or cubital deviation of the wrist.  
Intensity of effort: light task (less than 10% of maximum effort).
- ✓ **Neck:**  
Flexion between 10 and 20°.

**3.- PLACEMENT OF COMB IN MICROSCOPE: 30.0% of visual control of welds**

- ✓ **Arms:**  
Flexion between 45° and 90°.
- ✓ **Wrists:**  
Neutral posture.  
Intensity of effort: light task (less than 10% of maximum effort).
- ✓ **Neck:**  
Flexion between 10 and 20°.

**4.- OBSERVE PRESENCE OF WIRE AND WELD: 50.0% of visual control of weld**

- ✓ **Arms:**

Flexion between 20° and 45°.

✓ **Wrists:**

Neutral posture.

Radial or cubital deviation of the wrist.

Intensity of effort: light task (less than 10% of maximum effort).

✓ **Neck:**

Flexion greater than 20°.

**5.- REMOVAL OF COMB FROM MICROSCOPE: 10.0% of visual control of weld**

✓ **Arms:**

Flexion between 45° and 90°.

✓ **Wrists:**

Neutral posture.

Radial or cubital deviation of the wrist.

Intensity of effort: light task (less than 10% of maximum effort).

✓ **Neck:**

Flexion between 10 and 20°.

**6.- CUTTING OF TEETH WITH PINCERS: 100.0% of cutting of teeth**

✓ **Arms:**

Position between 20° extension and 20° flexion.

✓ **Wrists:**

Extension or flexion greater than 15°.

Radial or cubital deviation of the wrist

Intensity of effort: somewhat heavy task (between 10-30% of maximum effort).

✓ **Neck:**

Flexion greater than 20°.

**7.- COLLECTION OF CUT TOOTH: 30.0% of resistance control**

✓ **Arms:**

Position between 20° extension and 20° flexion.

- ✓ **Wrists:**
  - Extension or flexion between 0° and 15°.
  - Pronation or supination of the hand.
  - Intensity of effort: light task (less than 10% of maximum effort).
- ✓ **Neck:**
  - Flexion between 10° and 20°.

**8.- PLACEMENT OF TOOTH IN OHMMETER: 40.0% of resistance control**

- ✓ **Arms:**
  - Flexion between 20° and 45°.
- ✓ **Wrists:**
  - Extension or flexion between 0° and 15°.
  - Pronation or supination of the hand.
  - Intensity of effort: light task (less than 10% of maximum effort).
- ✓ **Neck:**
  - Flexion between 10° and 20°.

**9.- REMOVAL OF TOOTH: 30.0% of resistance control**

- ✓ **Arms:**
  - Flexion between 20° and 45°.
- ✓ **Wrists:**
  - Extension or flexion between 0° and 15°.
  - Pronation or supination of the hand.
  - Intensity of effort: light task (less than 10% of maximum effort).
- ✓ **Neck:**
  - Flexion between 10° and 20°.

**10.- FOLDING OF COMBS: 100.0% of storage of teeth**

- ✓ **Arms:**
  - Flexion between 20° and 45°.
- ✓ **Wrists:**

Extension or flexion greater than 15°.

Radial or cubital deviation of wrist.

Intensity of effort: light task (less than 10% of maximum effort).

✓ **Neck:**

Twisting of neck.

Flexion greater than 20°.

## **ATTACHMENT II**

### **RECOMMENDATIONS ON THE RE-DESIGN OF TASK: BIHLER**

Risk of problems or injuries on SHORT and MEDIUM TERM in NECK is level III.

Risk of injuries or problems LONG TERM in NECK is level IV.

Risk of injuries or problems in WRIST is level IV.

### **RECOMMENDATIONS TO REDUCE LEVEL OF RISK IN NECK**

To reduce risk of injury or problems in the neck on a short-term from level III to level II one of the following recommendations should be implemented:

- ◆ **Improve neck posture.**
- ◆ **Improve arm posture.**

To reduce risk of injury or problems in the neck on a medium-term from level III to level II one of the following recommendations should be implemented:

- ◆ **Improve neck posture.**

To reduce risk of injury or problems in the neck on a long-term from level IV to level III one of the following recommendations should be implemented:

- ◆ **Improve neck posture.**
- ◆ **Improve arm posture.**

## **RECOMMENDATIONS TO REDUCE RISK LEVEL IN HAND-WRIST**

To reduce the risk of injury or problems in the wrist from level IV to level III one of the following recommendations should be introduced:

- \* **Improve radial/cubital deviation and/or pronation/supination of the wrist.**
- \* **Improve the posture of the wrist.**

## **IMPROVE THE POSTURE OF THE ARMS:**

To carry out the improvement, action should be taken on the following postures:

- **PLACEMENT OF THE TOOTH IN THE OHMMETER (RESISTANCE CONTROL):** Pass from flexion between 20° and 45° to position between 20° extension and 20° flexion.
- **REMOVAL OF TOOTH (RESISTANCE CONTROL):** Pass from flexion between 20° and 45° to position between 20° extension and 20° flexion.

- **FOLDING OF COMBS (STORAGE OF TEETH):** Pass from flexion between 20° and 45° to position between 20° extension and 20° flexion.

### **IMPROVE POSTURE OF THE NECK:**

To carry out the improvement action should be taken on the following postures:

- **CUTTING OF TEETH WITH PINCERS (CUTTING OF TEETH):**  
Pass from flexion greater than 20° to flexion between 0° and 10°.

### **IMPROVE POSTURE OF THE WRIST:**

To carry out the improvement action should be taken on the following postures:

- ◇ **CUTTING THE TEETH WITH PINCERS (CUTTING OF TEETH):**  
Pass from extension or flexion greater than 15° to neutral posture.

### **IMPROVE THE RADIAL/CUBITAL DEVIATION AND/OR THE PRONATION/SUPINATION OF THE WRIST:**

To carry out the improvement action should be taken on the following postures:

- ⇒ **CUTTING THE TEETH WITH PINCERS (CUTTING THE TEETH):**  
Eliminate the radial/cubital deviation of the wrist.
- ⇒ **COLLECTION OF CUT TOOTH (RESISTANCE CONTROL):**  
Eliminate the pronation/supination of the wrist.
- ⇒ **PLACEMENT OF THE TOOTH IN THE OHMMETER (RESISTANCE CONTROL):** Eliminate the pronation/supination of the wrist.

## ATTACHMENT III

### ERGO-IBV – Job report - MODIFICATIONS TO THE BIHLER MACHINE.

#### JOB REPORT: MODIFICATIONS TO THE BIHLER MACHINE

- *Description of the job:*

List of activities associated with the task:

##### 1) SELECTION OF COMBS

Exposure: 10% of task.

Repetitiveness of arm movements: 0 rep/min.

Repetitiveness of hand movements: 15 rep/min.

Main postures taken into account:

- *EXAMINATION OF COMBS (100% of activity).*

##### 2) VISUAL CONTROL OF WELDS

Exposure: 10% of task.

Repetitiveness of arm movements: 1 rep/min.

Repetitiveness of hand movements: 1 rep/min.

Main postures taken into account:

- *PICKING UP COMB (10.0% of activity).*
- *PLACING OF COMB IN MICROSCOPE (30.0% of activity).*
- *OBSERVATION OF PRESENCE OF COMB & WELD (50.0% of activity).*
- *REMOVAL OF COMB FROM MICROSCOPE (10.0% of activity).*

##### 3) CUTTING OF TEETH

Exposure: 30% of task.

Repetitiveness of arm movements: 0 rep/min.

Repetitiveness of hand movements: 1 rep/min.

Main postures taken into account:

- *CUTTING TEETH WITH NEW SYSTEM (100.0% of activity).*

#### **4) RESISTANCE CONTROL**

Exposure: 40% of task.

Repetitiveness of arm movements: 0 rep/min.

Repetitiveness of hand movements: 1 rep/min.

Main postures taken into account:

- ***COLLECTION OF CUT TOOTH (30.0% of activity).***
- ***PLACEMENT OF TOOTH IN NEW OHMMETER (40.0% of activity).***
- ***REMOVAL OF TOOTH (30.0% of activity).***

#### **5) STORAGE OF TEETH**

Exposure: 10% of task.

Repetitiveness of arm movements: 1 rep/min.

Repetitiveness of hand movements: 1 rep/min.

Main postures taken into account:

- ***FOLDING OF COMBS (100.0% of activity).***

### ***Posture analysis***

#### **1.- EXAMINATION OF COMBS: 100.0% of selection of combs**

- **Arms:**

Position between 20° extension and 20° flexion.

- **Wrists:**

Extension or flexion between 0° and 15°.

Intensity of effort: light task (less than 10% of maximum effort).

- **Neck:**

Flexion between 10° and 20°.

#### **2.- COLLECTION OF COMB: 10.0% of visual control of welds**

- **Arms:**

Position between 20° extension and 20° flexion.

- **Wrists:**

Extension or flexion between 0° and 15°.

Intensity of effort: light task (less than 10% of maximum effort).

- **Neck:**

Flexion between 10° and 20°.

### **3.- PLACEMENT OF COMB IN MICROSCOPE: 30.0% of visual control of welds**

- **Arms:**

Flexion between 20° and 45°.

- **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

- **Neck:**

Flexion between 10° and 20°.

### **4.- OBSERVATION OF PRESENCE OF WIRE AND WELD: 50.0% of visual control of weld**

- **Arms:**

Flexion between 20° and 45°.

- **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

- **Neck:**

Flexion greater than 20°.

### **5.- REMOVAL OF COMB FROM MICROSCOPE: 10.0% of visual control of weld**

- **Arms:**

Position between 20° extension and 20° flexion.

- **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

- **Neck:**

Flexion between 10° and 20°.

**6.- CUTTING OF TEETH WITH NEW SYSTEM: 100.0% of cutting of teeth**

• **Arms:**

Position between 20° extension and 20° flexion.

• **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

• **Neck:**

Flexion between 10° and 20°.

**7.- COLLECTION OF CUT TEETH: 30.0% of resistance control**

• **Arms:**

Position between 20° extension and 20° flexion.

• **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

• **Neck:**

Flexion between 10° and 20°.

**8.- PLACEMENT OF TOOTH IN NEW OHMMETER: 40.0% of resistance control**

• **Arms:**

Position between 20° extension and 20° flexion.

• **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

• **Neck:**

Flexion between 10° and 20°.

**9.- REMOVAL OF TOOTH: 30.0% of resistance control**

• **Arms:**

Position between 20° extension and 20° flexion.

• **Wrists:**

Neutral position.

Intensity of effort: light task (less than 10% of maximum effort).

• **Neck:**

Flexion between 10° and 20°.

**10.- FOLDING OF COMBS: 100.0% of storage of teeth**

• **Arms:**

Position between 20° extension and 20° flexion.

• **Wrists:**

Extension or flexion between 0° and 15°.

Intensity of effort: light task (less than 10% of maximum effort).

• **Neck:**

Flexion between 10° and 20°.