BREAKING SMART
The future of hand-held demolition

Degree Project 2013
MFA Advanced Product Design
Philip Nordmand Andersen
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INTRODUCTION
**PROJECT SUMMARY**

**THIS REPORT** describes the work method, conclusions and result of my Master Degree in Advanced Product Design at Umeå Institute of Design. The project lasted 17 weeks and took place in Spring 2013. The project was carried out in collaboration with Atlas Copco.

The main purpose of this project is to explore the future of handheld demolition tools and how to carry out this extremely physically demanding work in an ergonomic and effortless way, while keeping productivity high and complexity low.

I will look into the area of robotics, compact machines, and exoskeletons to get inspiration for supportive structures that could potentially semi- or fully automate some of the strenuous movements of today's work, while trying to incorporate features to solve some of the other problematic aspects like the hazardous silica and asbestos dust spreading in the air and/or detecting hidden pipes and cables to avoid unnecessary interior damages. The result will be a conceptual product meant for the future market of 2025.
THE FUTURE OF HANDHELD DEMOLITION

COLLABORATION PARTNER
ATLAS COPCO
“The Atlas Copco Group's vision is to become and remain First in Mind—First in Choice ® of its customers and other key stakeholders” [Atlascopco.com]

‘COMMITTED TO SUSTAINABLE PRODUCTIVITY’ is Atlas Copco’s brand promise. This is a promise to ensure reliable, lasting results with a responsible use of resources – human, natural and capital.

Strategy
The group concentrates on strengthening its global position within segments where it has core competence. To reach the vision the group has three overall strategic directions.

1. Organic growth
2. Innovation and continuous improvements
3. Strengthened aftermarket

Increasing productivity is the foundation of all of Atlas Copco’s business activities. It means helping customers get more out of every investment. Be it making products faster, more energy efficient, safer or more ergonomic, the effect should be increased productivity.
ATLAS COPCO CONSTRUCTION TECHNIQUE

Compressor Technique
- Industrial Air
- Oil-free Air
- Gas and Process
- Quality Air
- Specialty Rental
- Compressor Technique Service
- Airtec

Mining and Rock Excavation Technique
- Underground Rock Excavation
- Surface Drilling
- Drilling Solutions
- Exploration and Geotechnical Drilling
- Rock Drilling Tools
- Mining and Rock Excavation Service
- Rocktec

Construction Technique
- Portable Energy
- Road Construction Equipment
- Construction Tools
- Construction Technique Service

Industrial Technique
- MVI Tools and Assembly Systems
- General Industry Tools and Assembly Systems
- Chicago Pneumatic Tools
- Industrial Technique Service
“Construction Technique develops, manufactures and markets hydraulic, pneumatic, and petrol-driven equipment for demolition, recycling, compaction, rock drilling and concrete applications”

[Atlascopco.com]
“Atlas Copco began to take an interest in ergonomics during the 1940’s, but at the time, interest from the market was limited. In 1960 however, the company could present its first ergonomically designed handheld tools” [AtlasCopco.com]

AS EARLY as the end of the 1940’s, Atlas Copco made the first attempts to introduce machines consciously designed to reduce injurious effects. These attempts were unsuccessful, since neither companies nor workers were aware of the risks. The company was too early with its ideas. But ten years later, the time was right.

In its ergonomic initiative, Atlas Copco worked with several different organizations and institutes, including Dr. Lennart Hamberg, who was studying the human-machine relationship. The problems that Atlas initially identified were in the areas of work physiology, noise reduction, vibration, air contamination and silicosis.

A tool series takes shape
The departure point for the 33 Series was the RAB 300 model, a well-known and effective machine that Atlas Copco wanted to replace with a quieter model with more power and greater capabilities for variation. But with increased power, the hand grip also had to be improved. During testing, it was soon be discovered that the grip was far from ideal. Atlas Copco then sought the medical expertise of Professor Fritof Sjöstrand from the Karolinska Institutet in Stockholm. Through his knowledge of the anatomy of the hands and of muscle and nerve centers, he created an anatomic model in plastic on the company’s behalf that came to constitute the fundamental shape of the new machine. With the model, he showed how the entire hand should grasp the machine without any abnormal, fatiguing, cramping grips.

Ergonomics not just for tools
Rune Zernell later became the chief designer for Atlas Copco’s products, and not just for handheld tools. Atlas Copco has also worked with other initiatives for improved working environments. At the beginning of the 1970’s, the company built an acoustics lab and began research on noise and vibrations. In 1986, a vibration-dampened chipping hammer could be presented, the first in a long series of vibration-dampening tools.

In the same year, Atlas Copco presented yet another pioneering ergonomic product, EroPulse – an ergonomically correct nutrunner. The influences of Rune Zernell’s designs can still be clearly seen in Atlas Copco’s tools.
1873
Atlas Copco founded, with Andre Oscar Wallenberg as one of the four founders

1901
Pneumatic department created and tool production initiated

1924
Atlas manufactured its first compressed air breaker used for breaking up packed earth, asphalt and concrete, and for construction work

1960
A new series of advanced pneumatic breakers is introduced, the TEX series

1966
Introduction of the world’s first serial-produced hydraulic breakers (patented)

1997
Launch of a new motor breaker, the Cobra mk1. The mk1 is the most powerful motorbreaker on the market and it meets exacting ergonomic and environmental demands

2009
Introduction of the new TEX PE hammer range with significant reduction of vibration and maximized ergonomics
RESEARCH
THE PNEUMATIC AIR COMPRESSOR is the original power source. It creates a lot of power, but it also has a very high energy loss. The hydraulic powerpack is very comparable in terms of performance. It is more compact and portable, has a lower energy loss, but it is also slightly more complex.

The motor driven petrol and electric breakers has the most efficient energy usage, but the petrol breaker cannot be used indoors and the electric breaker is heavier and has a weaker breaking force. No battery driven solution is realistic with todays technology in terms of size and weight.
BREAKERS TYPES & APPLICATION AREAS

PNEUMATIC / Air Compressor
— Wide range
— Big construction sites
— Simple/Reliable/Robust

HYDRAULIC / Power Pack
— Comparable to pneumatic
— Portability
— Power from vehicles

PETROL / Gas Tank
— Remote locations
— Outdoor
— Versatile usage

ELECTRIC / Cable
— Portability
— Easy power source access
— Light construction
**BREAKERS** PNEUMATIC SEGMENTATION

3-7 KG / Light hammers
Smallest D-handle configuration for work on vertical surfaces.
- Surface structural work
- Changing concrete surface
- Ornamental work

Rebuilding, renovation, repairs. Buy or rent the tools so rental companies is also a target group.

8-15 KG / Hammers
Relatively simple and small to carry around and work with — both horizontally and vertically.
- Renovation/Re-building
- Industrial applications (filmstripping)

Rebuilding, renovation, repairs. Buy or rent the tools so rental companies is also a target group.

15-30 KG / Breakers
T-handle configuration, for work on horizontal surfaces.
- Service work
- Infrastructural servicing
- Repairs on concrete/hard materials

Gas-, electricity-, water and sewage companies. The heavier ones for demolition jobs and renovation/rebuilding to a certain degree. Also quite popular with rental.

30-45 KG / Heavy breakers
T-handle configuration, for work on horizontal surfaces.
- Demolition

Non-EU heavy road construction, demolition specialist companies (demolition work where you cannot with any efficiency use robots).

45+ KG / Attachments
Hydraulic attachments. High flexibility and safety for work on floors, walls and ceilings.
- Demolition

The last 20 years quite a lot of substitution from automated vehicles with hydraulic attachments, has happened. The size varies from small Brokk 40 machines up to the largest 140 ton excavators.
Different breaker applications require different types of chisels. This project is focusing on concrete breaking which is one of the most common applications beside asphalt cutting.

**Concrete Breaking**
- **Chisels**
  - **Narrow chisel**: Good balance between working its way into the concrete and spreading force, making cracks.
  - **Mohl point**: Goes straight down (useful in steel-reinforced concrete).
- **Applications**
  - **Concrete Breaking**
  - **Asphalt Cutting**
  - **Compacting**

**FOR CONCRETE BREAKING**
The most common chisel is the narrow chisel. It has good balance between working its way into the concrete and also spreading the force, making cracks. The thinner mohl point just goes straight down (useful in steel-reinforced concrete) while the wide chisel would not work in hard concrete since it stays on the surface, spreading the energy too much (useful in the softer asphalt). As a rule of thumb you should always use the widest chisel that the material allows you to.
For the cobra series, which is used in more remote locations, a range of transport and storage accessories are available. The plastic and aluminium parts makes the Cobra breakers more fragile than the sturdy pneumatic breakers.
COMPETITORS  PNEUMATIC PREMIUM BRANDS

Compared to their premium competitors it becomes clear that Atlas Copco is superior in terms of product design and identity.

THE PERFORMANCE cannot be compared since Atlas Copco is keeping the numbers a secret. They are afraid that their competitors will use the numbers against them, claiming better values even though it might not be true. They do not want to enter a discussion like that.
“When the electric tools emerged the Swedish workers went away from the pneumatic tools. They were considered old fashioned”

-Jan Ohlsson / AC marketing

**ATLAS COPCO** Used to have electric breakers in their portfolio (AEG, Milwaukee and Kango), but the sold them out since they did not feel competitive enough in 2003.

No one in Umeå uses 30kg breakers, but I found that the lighter Hilti TE 1000 was very popular. Since it is vibro-reduced and weighs only 12kg, it is possible to work longer time, be more precise, and even use it for walls to some extend.
**COMPETITORS** VIBRATION EXPOSURE LIMITS

The past few years Atlas Copco have reduced the vibration exposure significantly with their vibro-reduced models.

The **Exposure Limit Value (ELV)** is 5 m/s²
- The red area = immediate action to stop

The **Exposure Action Value (EAV)** is 2.5 m/s²
- The orange area = establish action plan

\[
T = T_0 \left( \frac{A}{a_{3av}} \right)^2
\]
- \( T \) = time operator is exposed to vibrations (h)
- \( T_0 \) = the reference value of duration (8 h)
- \( A \) = The daily VBR exposure value (m/s²)
- \( a_{3av} \) = 3-axes VBR value for machine (m/s²)

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**COMPETITORS**

- **TEX 230** (VBR)
  - 8+ hours
  - 28 hours

- **Cobra Pro**
  - 8+ hours
  - 25 hours

- **LH 230 E HBP** (VBR)
  - 8+ hours
  - 25 hours

- **TE 3000-A VR**
  - 4.1 hours

- **TEX 270PS**
  - 8+ hours
  - 2 hours

- **BH 24** (VBR)
  - 758 hours
  - 4.1 hours

- **LH 270**
  - 36 min

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**Vibration 3-axes value**

- **TEX 230**
  - 8+ hours
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  - 2 hours

- **BH 24** (VBR)
  - 758 hours
  - 4.1 hours

- **LH 270**
  - 36 min
The vibro-reduced Atlas Copco breakers have the lowest vibration exposure values on the market of today. They can be used a full workday without reaching the 'Exposure Limit Value'...
COMPETITORS  COMPACT DEMOLITION ROBOTS

All the solutions are of high mechanical complexity, which makes them big and expensive.

THE MECHANICAL COMPLEXITY is needed because the robots have a high range of motion, being able to demolish both floors, walls and even ceilings. All solutions, except ERO, function as multi-tools. By changing the tool on the arm they can saw, dig, drill and grab/lift/move. The robots are very versatile but also very expensive. The precision is also far from that with a handheld tool, due to lack of control with the remote.
An opportunity for a more compact solution with supportive features, making demolition more ergonomic and less physical.
"Ergonomics is a science focused on the study of human fit, and decreased fatigue and discomfort through product design" [allsteeloffice.com]

**THE HUMAN BODY** has a natural range of motion (ROM). Movement within the proper ROM promotes blood circulation and flexibility which could lead to more comfort and higher productivity. Despite the need to promote motion, users should try to avoid repetitive movements and certain extremes in their ROM over long periods of time. By considering both ROM and repetitive motion, products can be designed to operate within the optimal ranges to help reduce the occurrence of fatigue and muscle disorders.

**Good and Bad Zones**

There are four different zones that a user might encounter while sitting or standing. Zones 0-1 include smaller joint movements, which is preferred for most work tasks. Zones 2-3 represent more extreme positions, which should be avoided when possible especially for repetitive and heavy tasks. Motion in these ranges puts more strain on muscles and tendons and could lead to the development of musculoskeletal disorders. [Allsteeloffice.com]
“I don't think you can work in this job until you are 65. You will break your body before that!” [Fredrik / Laborer]
Forceful exertions place high loads on muscles, tendons, ligaments, joints and discs. Muscles fatigue with increased exertion and need more time to recover. If soft tissue does not have time to recover, injury is likely to develop over a period of time. If the exertions are forceful enough, body tissues may be damaged immediately.

Forceful exertions include forces exerted by muscles, such as when lifting items, carrying loads, holding one position for a period of time, or using a forceful grip. Exposure to forces also occurs as a result of external forces applied to the body, such as the weight of a load being carried, or when jumping down when getting out of mobile plant.

It should be noted that it is the amount of force relative to the capability of the tissue which is important. For example, the small tissues of the hand may be injured by relatively low forces. [DEIR]

Muscular effort may be increased by:
- Awkward or fixed working postures
- Heavy, bulky, unstable or difficult to grip loads
- Fast, sudden or jerky movements
- Vibrating tools that need more effort to grip
- The way loads are handled (e.g. physically lifting, pushing, pulling or carrying)
Exposure to hand-arm vibration occurs when working with pneumatic, hydraulic, electric, or petrol powered tools. Exposure to hand/arm vibration primarily damages vascular and nerve tissue, typically of the hand and fingers. Prolonged exposure can eventually result in Hand-arm Vibration Syndrome (HAVS), where the blood vessels and nerves in the hands and fingers are damaged causing numbness, tingling, pain, loss of grip strength, reduced sensation touch and in some cases blanching of fingers.

When the body or limbs are exposed to vibration, the force of this movement is absorbed by the body’s skin and the musculoskeletal system. Intermittent exposure to vibration may allow sufficient time for the soft tissues to recover between periods of exposure. However, long duration or frequent vibration exposure will significantly increase the risk of musculoskeletal injury. [DEIR]

Repetition means making the same type of movements over and over (e.g. laying bricks). The work cycle is the time taken to perform the task once without interruption (e.g. the time to lay one brick). Tasks involving short cycle times (less than 30 seconds) and performed for more than one hour, are considered to be a risk because the same muscles and other soft tissues are being used continuously. This contributes to their fatigue and risk of injury. Tasks involving longer cycle times and shorter task duration will have a lower risk of injury. [DEIR]
The term awkward postures refers to any posture where the body parts are away from their comfortable, neutral position (e.g. a bent back, a bent wrist or arms raised above the head. Awkward postures result in stretching or shortening of the connective and nervous tissues. As a result, the functional capacity of muscles can be reduced and the tissues are at greater risk of injury. Awkward postures are not always harmful. It is only when they are repeated frequently or performed for a long time.

The term fixed or static postures refers to postures where part of or the whole body is kept in the same position for a long period of time (e.g. standing in one position with no movement). Static postures quickly fatigue muscles because blood flow is more restricted due to the lack of muscle movement. This can lead to blood pooling and a lack of blood supply to some areas of the body and increase the risk of injury. [DEIR]

Duration is the time taken to perform the task once, or perform the task repeatedly without a break. The longer a task takes, the greater the cumulative load on the musculoskeletal tissues. If the same musculoskeletal tissues are loaded without a break for extended periods, then the mechanical properties of those tissues begin to change, decreasing their functional capacity and increasing the likelihood of injury. Duration may be considered as a significant risk factor when a task is performed continuously for one hour or longer. [DEIR]

Awkward or static postures can be caused by:

- Work area design (e.g. working at ground level or overhead)
- Handling bulky, heavy or large loads
- Poorly designed hand tools
- Pushing, pulling, or carrying loads which block the worker’s view
- Performing tasks which require loads or body parts to be supported or held for some time
Many construction workers complain that they can’t hear as well as they used to, and statistics back them up. Laborers and other construction workers are exposed to noises loud enough to cause permanent noise-induced hearing loss.

Breakers are some of the loudest tools, creating noise levels as high as 100 dBA – much higher than the exposure limit of 85 dBA recommended by the Occupational Safety and Health Administration (OSHA). At these noise levels it only takes repeated exposures of as little as 1 hour per day to damage the hearing and therefore wearing extensive hearing protection is a must. Of course this also applies for other people positioned near the breaker.

Workers who have suffered hearing loss often become socially isolated because they can’t communicate easily with others. They also may not be able to hear warning signals, which can lead to accidents and injuries. [OSHA/DEOHs]

Silica dust is a primary hazard for the construction industry which has been under estimated due to lack of sufficient documentation. Silicosis is caused by exposure to crystalline silica (inhalation) and has caused more deaths in construction than any other industry.

The percentage of construction laborers with chest x-ray findings of asbestos or silicosis is nearly 16%, and more than 40% had abnormal pulmonary function tests (PFTs ), a measurement of how well the lungs take in and release air and move gases such as oxygen from the atmosphere into the body's circulation. With age and years worked the numbers clearly increase. For instance 55% of workers over 65 had abnormal PFTs.

The best way to protect workers from lung hazards is to prevent the substances from being released into the air, through controls such as ventilation and dust suppression with a mist water. When such methods are not feasible, employers can provide workers with respiratory protection meeting the official standards. [Cpwr.com / Ncbi.nlm.nih.gov]
“In a recent survey, 40 percent of construction workers said "working while hurt". Working while hurt reduces productivity. Continuing to work while hurt will result in disabling injuries that can end a career. Many laborers end up retiring by age 55 because they just can't do the work anymore. Many can't enjoy their retirement because of their disabilities” [Lhsfna.org]

THE WORK ENVIRONMENT for construction workers have improved a lot over the years and especially for laborers. From 1992 to 2005 the rate of serious nonfatal injuries and illnesses has dropped significantly by 55% (chart A). Still in 2011, of all industries, construction had the third highest rate for nonfatal injury and illness cases with days away from work (chart C). With 34.7%, "sprains and strains" (or musculoskeletal injuries) are the leading cause of these injuries, followed by "fractures" (11.5%) and "cuts and lacerations" (11.3%).

But, findings indicate that construction nonfatal injuries and illnesses are vastly underreported, especially by small establishments/contractors, or those with 10 or fewer wage-and-salary employees. Among these small contractors, estimated numbers suggest that 75% of nonfatal injuries to Hispanic workers are not reported, and 40% of injuries are unreported for white, non-Hispanic workers. [Ncbi.nlm.nih.gov]
**STATISTICS CONSTRUCTION INJURIES**

**Chart C.** Incidence rates for nonfatal injury and illness cases with days away from work, job transfer, or restriction (By private industry sector, US, 2011)

*Incident rate (per 100 full-time worker)*

- Transporting and warehousing: 2.3 / 1.1
- Agriculture, forestry, fishing and hunting: 1.8 / 1.4
- Construction: 1.5 / 0.7
- Healthcare and social assistance: 1.4 / 1.0
- Arts, entertainment, and recreation: 1.2 / 0.9
- Retail trade: 1.2 / 1.0
- Real estate, rental, and leasing: 1.1 / 0.6
- Manufacturing: 1.1 / 1.3
- Wholesale trade: 1.1 / 0.9
- Accommodation and food services: 1.0 / 0.5
- Administrative and waste services: 1.0 / 0.5
- Utilities: 1.0 / 0.9
- Mining: 0.9 / 0.5
- Other services (except public adm.): 0.9 / 0.4
- Educational services: 0.6 / 0.3
- Information: 0.6 / 0.3
- Management of companies and enterprises: 0.4 / 0.2
- Professional and technical services: 0.3 / 0.1
- Finance and insurance: 0.2 / 0.1

Days of job transfer or restriction only cases

Days away from work cases rate

Focus (Days away from work cases rate)

“Work-related injuries and illnesses mean losses not only to workers, but also to their families, employers, and society. Calculating an accurate estimate of these costs is difficult for many reasons. Some costs, such as wage replacement and medical payments, can be measured directly, but others, such as a family's pain and suffering, are almost impossible to quantify”

[Cpwr.com]

**MANY COSTS** are not compensated, partly because they are difficult to link to specific work exposures. Construction workers may move among several employers in a year or even dozens of employers in a career. Work-related musculoskeletal disorders, which can be extremely costly in expense and suffering, often develop through repetition over months or years. Similarly, work-related illnesses, such as cancers or nervous system diseases, may not appear for many years after exposures to asbestos, solvents, or other toxics in the workplace. Therefore, the estimates reported here are only a rough measure and may differ from estimates in other publications due to different measurements.

The total cost of fatal and nonfatal injuries in the construction industry is estimated at nearly $13 billion annually. Deaths are estimated to be 40% of the total, and nonfatal injuries and illnesses, mainly injuries with days away from work, represent 60% of the total cost (chart A). On average, a nonfatal injury involving days away from work costs approximately $42,000. These estimates include direct costs (such as payments for hospitals, physicians, medicines), indirect costs (wage losses and household production losses, costs of administering workers’ compensation), and quality-of-life costs (value attributed to the pain and suffering that victims and their families experience as a result of injuries or illnesses).

Laborers ranked the highest in costs for both fatal and nonfatal injuries in construction. For costs of nonfatal injuries, laborers accounted for almost $2.1 billion (chart C). Several occupations, including roofers, construction laborers, and structural metal workers, ranked high for both total costs of injury and per-worker costs, suggesting that these occupations should be targeted for injury prevention programs and safety enforcement activities.

Employers in construction spend more on workers’ compensation than employers in any other industry. In 2005, 5% of employer costs in construction were spent on workers’ compensation (chart B), more than double the costs for manufacturing employers, and nearly three times the average cost employers in all industries. [Cpwr.com]
Statistics

Construction Injury Costs

Chart B. Employer spending on workers’ compensation, by industry, 2005
(As percentage of total compensation)

- Construction: 5.0%
- Goods producing: 3.1%
- Manufacturing: 2.2%
- Service providing: 1.6%
- All industries: 1.9%

Chart C. Estimated costs of work related injuries selected construction occupations
(All types of employment)

- Millions of dollars (2002 dollars)
  - Laborer: $3.290
  - Carpenter: $1.945
  - Electrician: $971
  - Plumber: $602
  - Roofer: $598
  - Supervisor n.e.c.: $525
  - Truck driver: $431
  - Painter: $412
  - Structural metal worker: $400
  - Helper: $380
  - Drywall: $308
  - Op engineer: $269
  - Brickmason: $262
  - Const. trades n.e.c.: $248
  - Welder and cutter: $192

LAb-or-er [ley-ber-er]
A person engaged in work that requires bodily strength rather than skill or training; a laborer in the field. [Dictionary.com]
“We don’t just work 15 minutes an hour, then it would take a hole year to get the job done”
"You can work with it 15 min each hour and then you need a 45 min break, but that never happens [...] You work with it to the job is done!"
“The floor is pretty easy... For the shoulders [compared to the walls]”
“It’s paid training”
“I still feel it in the shoulders from yesterday... That I worked out a little bit”

“Working with floors you often try to go under and break it up, then you use your shoulders a lot”
“You have to move the breaker a lot to hit the concrete from different angles”
“If you use hydraulic [breakers] then you need a power pack and it’s too clumsy and too heavy to bring around”
“If you just hit straight down nothing happens. The chisels are often angled down, because then you get a better break in the concrete”

“I hate working with jackhammers! Maybe for 1 hour because it’s good exercise, but I’m more of a robot kind of guy”
“You don’t have the same type of control if you just type something in and then it should do that [...] I’m not all for fully automatic”
“I have tried some older hand tools and the difference is significant... Amazing actually!”
“The versatility is important, but if you have a lot of money [an autonomous more specialized machine] is great because you save a lot of time”

“I don’t think you can work in this job until you are over 65. You will break your body before that”
“If we are working longer than 0,8 hours with the Hilti a day, the company has to find other ways for us to do the job. We should use those machines as little as possible”
“It’s a good thing we wear this masks, otherwise all this shit would be in my lungs. Some of those we work with don’t use these masks. They say they don’t like it...”
“Hilti are the best at making low vibration tools. They are very good! You can use the TE-1000 longer than any of the similar tools from the other brands”

Is hose in the way? "The most times you are on one spot like in the bathroom working on the drain"

“There’s a lot of machines and they all have the same problem — you can only use it for at limited amount of time”

“The companies want it to be more ergonomic, so it has to be more ergonomic. They don’t want their guys to retire 5 years early”

“People were just laughing at the Hilti 3000 — there’s no way we are taking that thing!”

“The thing that is hard about the Brokk robots is to do precision work, which is one of the reasons why they are still using hand tools”

“If we liked to we could take away wide weight [...] but then we would need to reduce the power”

“When you ask the operators how much they have worked they say a full day, 8 hours, and when you look at the clock seldom more than 2 hours, because they are doing so much more”

“In many cases the one who buys it just want the lowest price. They don’t care about the operators that much. It’s very seldom the buyer that is the user”

“Sweden used to be a market where vibration and performance were high value items and now they are going for the worst solution available”

“We are working both sides of this market — the Brokks robots and tools for lighter jobs that still need to be handheld”

“There is too little knowledge in the young guys today. They think that everything that’s electric is simple so therefore it’s good. The problem is it’s simple but not good!”
“Nobody cares about these 45 minute rules. You use the machine until the work is done. But it's always a free choice!”  [Markus / Construction Manager]
FIELD RESEARCH OBSERVING BREAKER USAGE

Hilti TE-1000 / Electric
12 kg, Vibro-reduced
- Bad posture and ergonomics
- Tool slides off sides
- Holding chisel in place with foot

Hilti TE-700 / Electric
7 kg, Vibro-reduced
- Only vertical work
- Pressing tool a lot against the wall
- Lower parts promotes bad posture and ergonomics

Hilti TE-905 / Electric
12 kg, Vibro-reduced
- Light floor work (not so hard concrete)
- Often gets stuck and is hard to pull out
- Using as crowbar to break away concrete
- Unergonomic posture and ergonomics

DeWalt D25980K / Electric
31 kg, Vibro-Reduced
- The high weight makes it extreme heavy to constantly lift hard to reposition
- Becomes even harder when it gets stuck with occur often
- Changes handle-grip all the time
FIELD RESEARCH  COMPARING BREAKERS

**Hilti TE 1000-AVR / Electric**
12 kg, Vibro-reduced

— Much heavier than it looks!
— Slide off sides and then I have to carry the whole weight. Not just of the tool but also the force I push it down with
— Feels very efficient and breaks away the concrete with ease (not sure how hard it was)
— Good grip on middle-handle for lifting and manoeuvring

**Hilti TE 905-AVR / Electric**
12 kg, Vibro-reduced

— Good, active body stance
— The 905 is weaker than the 1000 and has more vibration.
— Good choice for light concrete where you constantly have to lift and reposition

**DeWalt D25980 / Electric**
31 kg, Regular handles

— Very heavy but also efficient
— Becomes hard to lift and position
— Wrists starts hurting during lifting (when the tool is highest from the ground)
FIELD RESEARCH  COMPARING BREAKERS

**TEX P90 / Pneumatic**  
43 kg, Regular stiff handles  
— Very heavy (half my own weight!)  
— Hard to maneuver / position  
— Very efficient breaking  
— High vibration level

**TEX 230 / Pneumatic**  
28 kg, Vibro-reduced  
— Small and compact  
— Easy to maneuver  
— Low vibrations  
— Feels very efficient / Fierce

**COBRA PRO / Petrol**  
25 kg, Vibro-reduced  
— Heavy to maneuver  
— Unbalanced / top heavy  
— Hard to see chisel  
— Good vibration reduction

**Wacker / Electric**  
25 kg, Vibro-reduced  
— "Amazing difference!"  
— Weak, slow and dull  
— Feel vibrations more  
— Porche 911 vs. Skoda Felicia

**Notes:**
- **Cobra Pro** is heavy to maneuver due to its unbalanced weight.
- **TEX P90** is difficult to maneuver and position, and very heavy.
- **TEX 230** is effective but feels like it has high vibration levels.
- **Wacker** is the least efficient but offers a good difference.
STEP 01 / Bring Tools
— The breaker easily fits in the back of the van among the other tools
— Fredrik has problems getting the breaker out of the van. It almost fall out of the trolley
— Lift breaker down the stairs rather than sliding or using the trolley wheels

STEP 02 / Removing Interior
— Interior elements are removed from walls/floors with hammers and crowbars, and are carried outside to create space for the floor demolition
— It takes about 15-20 min before everything is removed (with my help)

STEP 03 / Dust Sealing
— They carefully seal of first the ceiling and afterwards the doors with thick plastic and a stapler to contain the dust in the work space
— An opening is made towards the exit
— The sealing takes around 15 min

STEP 04 / Air Cleaners
— They bring in additional dust cleaning tools which are hard to get through the plastic sealing without ripping it off the walls.
— The vacuum cleaner stays outside while the air cube is brought into the space, where it often would be in the way when working
FIELD RESEARCH  WORKFLOW EXAMPLE OCAB

**STEP 05 / Breaking**
- It takes an extra person to operate the manual vacuum cleaner
- Often the chisel gets stuck and it usually happens if the concrete pieces chipped off are pushing against the piece about to break off
- In general the breaker seems like a too heavy duty tool for this light demolition job

**STEP 06 / Moving Debris**
- Making small (maximum fist size) concrete pieces to make it easy to shovel into a plastic bag or suck out with a van connected hose
- A hammer is used to manually smash the concrete pieces into smaller pieces and to pull away the pieces near the breaking area

**STEP 07 / Packing Tools**
- They are 2 workers to carry out the tool to the van, but only a single worker lifts it into the van which looks like a very strenuous pull
- The most of the other tools remains to continuing the job the following day

**EXTRA / Asbestos Test**
- During the day the workers was in doubt if the floor material in one of the smaller rooms was containing asbestos. They called in a guy which took a sample that he delivered for a test back in Umeå. It was negative.
- Only special trained teams can work with asbestos materials
CONCLUSIONS
INSIGHTS

PROBLEM AREAS

Transport  Environment  Usage

TRANSPORT  ENVIRONMENT  USAGE
Transport

Storage [Size + Space]
Load/Unload [Grip + Weight]
Transport [Workers + Trolley]
Stairs [Workers + Trolley]
INSIGHTS
PROBLEM AREAS

Environment

- Corner [Reach + Size]
- Pipes + Cables [Hidden]
- Edge [Uneven]
- Debris [Low movability]
- Dust [Protection]
- Noise [Environment]
- Hole [Limited space]
INSIGHTS  PROBLEM AREAS

Usage

- Drop [Sudden movement]
- Lift + Position [Weight + Stuck]
- Posture [Height + Visibility]
- Crowbar [Stuck + Big break]
INSIGHTS BREAKING TECHNIQUE

DEMOLITION PATTERN / Topview example
The operator faces towards the hole, moving from one wall to the other — then one step backwards to repeat in the opposite direction. In a real environment the pattern might turn out less structured due to certain obstacles in the interior or other objects in the way like the aircube.

ORIENTATION / Sideways movement
The floor is weakest towards the hole so the operator always breaks towards the hole, which makes the overall workflow mainly a sideways movement. The floor near the wall is the hardest part to break, since concrete has nowhere to travel, so the operators tend to start with a distance to the wall.

CHISEL ANGLE / Optimized breaking energy
Holding the breaker/chisel in a vertical position is not very effective, since the impact energy is not spread in a proper way. The chisel works its way down into the concrete but in most cases it does not break off any concrete. Holding it with an angle, working your way against the whole is the most effective way.
To remove the debris, usually another worker will assist by using his hands or another tool like a hammer or a crowbar. One problem is that they cannot use the non-vibro gloves since they easily get damaged and they are very expensive.

During my research, I encountered 2 different scenarios. The most common would be to break off as big pieces as possible, because it's faster and you have to lift the tool less, but also some workers tried to create pieces smaller than a fist size (tennis ball) to make it easy to move manually with a shovel or suck it up with a big truck mounted vacuum cleaner.
**MOVABILITY / Work from different angles**

To be able to work in an efficient way the workers have to have a certain freedom of movement, being able to work the concrete from different angles. A fixed angle decrease efficiency, since there is no optimal angle. It depends. Lower efficiency might be compensated with increased power it is the case with the Brokk robots where you mainly work from one angle.

**WEIGHT DILEMMA / Power vs. Ergonomics**

An interesting fact is that the breakers could easily be made lighter, but they need to be heavy because weight and power is directly connected. If you want more power in the tool you will have to increase the weight as well.

The total weight is calculated as the weight of the tool plus 15-20 kg in feed force from the operator (pushing the tool downwards), depending if the handles are vibration reduced or not.
INSIGHTS TOOL & MACHINE USAGE

Time is money!

EFFICIENCY

<table>
<thead>
<tr>
<th></th>
<th>Precision / Feeling</th>
<th>Breaking Power</th>
<th>Time / Endurance</th>
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FLEXIBILITY

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<th>Range (floor, wall, roof)</th>
<th>Accessibility</th>
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<tr>
<td></td>
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<td>Big Spaces</td>
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<td>Big/Small Spaces?</td>
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PORTABILITY

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<th>Size / Weight</th>
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ECONOMY

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Big Spaces Small Spaces Big/Small Spaces?

Time is money!
CONCLUSIONS  COMPACT DEMOLITION ROBOTS

Optimized for bigger spaces and heavy demolition tasks:

- "Unlimited" working time
- Breaking power
- Versatility/multi-tool
- Range (floor, wall roof)

Problematic in small spaces with less accessibility and more sensitive tasks:

- Lack of precision/control
- Low portability (transport, stairs)
- Physical size in room (visibility, safety)
- Mechanical complexity (maintenance, cost)
CONCLUSIONS  FUTURE VISION

“There's a lot of machines and they all have the same problem, you can only use it for a limited amount of time” [Johan / Sales]
CONCLUSIONS  OPPORTUNITY MAPPING

Heavy Demolition  Demolition  Renovation

Auto

Remote

Support

Physical

Physical

A solution close to the existing design
Smart supportive features
Increased work duration and ergonomics
Medium cost

Remote controlled compact vehicle
Great work duration and ergonomics
Dust prevention
High cost

Autonomous/Manual Compact robot
Optimal work duration and ergonomics
Dust prevention (+Hazardous environment)
High cost (but low worker salary!)
GOALS AND WISHES DESIGN OPPORTUNITY

GOAL

• Demolish horizontal concrete surfaces (floors) in an ergonomic and effortless way
• Maintain the original weight of the breaker, while making it feel lighter and cause less strain on the operators' body
• Compact and portable solution, easy to transport and re-position
• Future market year 2025

WISH

• Integrated dust prevention
• Increase vibration exposure awareness
• Asphalt cutting (road construction)
TECHNOLOGY
“An autonomous robot would be awesome because we have hundreds of tons of floor down stairs. If you could just type something in and then it goes from wall to wall like a robotic lawn mower.” [Alex/ Brokk Operator]
TECHNOLOGY

CONCEPTUAL DIRECTIONS

Muscles  Supportive  Remotely  Autonomous

SUPPORTIVE  REMOTELY  AUTONOMOUS
As an extension of the body's natural movement, supportive machines and robotic structures enhance the performance of the human body beyond its normal capabilities — providing people with supernatural strength, endurance, and speed. The examples so far appear to be more a technology statement rather than realistic, useful product solutions.

**Walking Assist / Honda**

As a walking aid, a motor helps lift each leg at the thigh as it moves forward and backward. This helps lengthen the user’s stride, making it easier to cover longer distances at a greater speed. A lightweight, simple design with a belt worn around the hips and thighs was created to reduce the wearer’s load and to fit different body shapes. [Corporate.honda.com]

**HULC / Lockheed Martin**

The HULC is a completely un-tethered, hydraulic-powered anthropomorphic exoskeleton that provides users with the ability to carry loads of up to 200 pounds for extended periods of time and over all terrains. Its flexible design allows for deep squats, crawls and upper-body lifting. [Lockheedmartin.com]

**UNI-CUB / Honda**

The Honda UNI-CUB is the world’s first omnidirectional driving wheel system and is equipped with Honda Omni Traction Drive System (HOT), and proprietary balance control technology. Featuring a compact design and comfortable saddle, UNI-CUB offers the same freedom of movement in all directions that a person enjoys while walking. [Horsey, J.]
Ways of controlling a machine without physically touching it. The most traditional method would be a remote control with joysticks as we see it with the Brokk robots, but other methods are starting to emerge. For instance the Kinect made gesture based controls cheap and accessible, while the advanced, sophisticated technology of the ExoHand makes it an unlikely candidate for the field of construction.

Demolition Robots / Brokk
The Brokk Robot is a boom-mounted hammer extending from a compact, track-driven power unit, capable of precisely cutting steel-reinforced concrete, brick, block, asphalt and stone of any dimension and size. Because of its compact size and remote operation, the Brokk Robot is very agile and highly manoeuvrable, making it ideally suited for sensitive job sites, confined spaces and dangerous work areas. [Cuttingtechnologies.com]

ExoHand / Festo
The ExoHand system comes in two parts; the first is a glove apparatus, and the second is the robot arm itself. When the operator moves the arm it triggers the actuators on the glove, translating it into a corresponding movement of the robot arm. The communication goes both ways. Force feedback in the glove helps the human operator to know how much force is being applied to any object the arm is manipulating. [Whittam, R.]

Kinect / Microsoft
Kinect is a motion sensing input device by Microsoft for the Xbox 360 video game console and Windows PCs. Based around a webcam-style add-on peripheral for the Xbox 360 console, it enables users to control and interact with the Xbox 360 without the need to touch a game controller, through a natural user interface using gestures and spoken commands. [En.wikipedia.org - Kinect]
Autonomous robots are getting more and more common. They are usually specialized for monotonous and repetitive tasks. Around the house hold robots will be able to do simple tasks like lawn mowing or vacuum cleaning. Since these tasks normally do not harm people, these robots are more like a luxury help and I think it would make even more sense to use this autonomous technology in construction where it can do a difference.

**Baxter / Rethink Robotics**
Baxter is a relatively inexpensive new industrial robot, that can reportedly be trained to perform tasks by physically guiding it through the required motions, within less than half an hour – no code-writing required. Once it has learned a task, it is said to be able to apply common sense to what it’s doing. If it should drop an item, for instance, it will realize that it needs to get another one in order to complete its task. [Coxworth, B.]

**Roomba / iRobot**
Roomba is a series of autonomous robotic vacuum cleaners. Under normal house conditions, it is able to autonomously vacuum the floor while navigating a living space and avoiding obstacles. The robot’s contact-sensing mechanical bumper detects bumping into walls and furniture, reversing or changing path accordingly. [En.wikipedia.org - Roomba]

**Asimo / Honda**
ASIMO stands for Advanced Step in Innovative Mobility, and is the most advanced humanoid robot in the world, that can walk independently and climb stairs. It can also understand preprogrammed gestures and spoken commands, recognize voices and faces. Honda wanted to create a robot that would be a helper for people, around the house, help the elderly, or help someone confined to a wheelchair or bed. [Obringer, L.]
Alternative methods of breaking concrete are limited. Several of the methods I found are considered dangerous, which could create a lot of safety issues if they are to be used in residential areas. An interesting method is EcoBust which creates a "slow explosion", breaking the concrete over several hours. But, the method is rather inconvenient, since there is a lot of steps and it takes a lot of planning.

**RAPTOR / Brookhaven National Laboratory**

RAPTOR is an award winning technology, that claims to be quieter, safer more efficient and environmental friendly alternative to the conventional jackhammer. It uses a helium-driven gas gun to accelerate projectiles such as steel nails to about 5,000 feet per second. The 6.5-foot long, 265-pound device can break up six-inch-thick concrete. [Brookhaven National Laboratory]

**Robot 324 / Conjet**

Conjet Robot 324 is a small water jetting machine which revolutionises the hydro demolition industry with its compact design and flexibility. The small Robot 324 opens up new areas for mechanising concrete removal with superior bonding due to absence of micro cracks and replaces inefficient hand lancing and jack-hammering and other percussive methods. [Conjet.com]

**ECOBUST / Brookhaven National Laboratory**

Expansive Demolition Agent for breaking all rock or concrete without the use of explosives or jackhammering, that works for big and small jobs. There are 4 different kind of mixtures that works with different temperatures to match the different seasons of the year. [Ecobust.com]
Accordingly to Atlas Copco there are no successful dust extraction solutions (spot) for breakers on the market today. They are too clumsy to move around with and they are blocking for the work area (chisel). Also, the workers admit they do not bother to bring the dust extraction equipment along since it is just too much a hassle.
IDEATION
The Workshop Rules:
1) Create 3 ideas in 5 minutes and send the paper left.
2) Get inspired and create 3 new ideas. This process continues 3 times for a total of 9 ideas per A3 sheet.
IDEATION | ATLAS COPCO WORKSHOP — IDEATION EXAMPLES

— Ergonomics / Support

— Chisel visibility
IDEATION ATLAS COPCO WORKSHOP — IDEATION EXAMPLES

— Robotic mobility

— Alternative demolition principles
IDEATION  ATLAS COPCO WORKSHOP — SELECTED IDEAS

- Supportive harness
- Chisel feeding
- Support leg with wheel
- Support stand
- Handle adjustment
- Push-off tube
- Compact specialized robot
- Transport in separate parts
From supportive handheld solutions to autonomous robots — chosen concept direction.
A compact solution with supported movements, more tool rather than robot, trying to minimize technical complexity.
Function Analysis

Overview of the product functionality that needs to be explored in the ideation phase. There is a focus on movability since that is the main thing that needs to be solved while the other (grey) functions are also important but can easily be implemented in various solutions.

**Usage**
- Sideways work
- Low angle support
- Chisel Lift/release
- Chisel precision
- On/off
- Breaking start/stop
- Pipe/cable UI
- Vibration surveillance

**Environment**
- Corner reach
- Move on debris
- Difficult access
- Dust prevention
- Pipe/cable detection
- Cord management

**Transport**
- Transport (A-B)
- Lifting (in/out van)
- Stairways
- Compact storage
**Mockups Concept Exploration**

**01 Mockup**

**Low angle support**
During lower angle work the backwards rolling legs supports the weight of the breaker making it easy for the operator to perform this type of work.

**Transport**
With the 2-wheel construction the breaker has enough stability to be able to transport it with only 1 hand.
**Stand upright**
Due to its tripod-like stand, the breaker can stand upright instead of having to put it on the ground, making it easy for the operator to leave it or start working again.

**Chisel position**
With the chisel positioned in the middle of the volume, the operator has to bend unnecessarily forward to see the chisel tip.

**Sideways workflow**
In order to work sideways, the operator has to roll backwards with an angle and then forwards with an angle, which feels unnecessary only having to move 20 cm to the side.

**Limiting stability**
The stable construction with 2 wheels feels supportive during transport but limiting during breaking where the operator wants to move freely.

**Wide body**
With the 2 wheels rolling backwards, the operator needs to take an unnatural wide stance to avoid the wheels from colliding with the feet.
**Mockups Concept Exploration**

02  
Mockup

**Chisel pull-out**
When the leg rotates inwards it forces the chisel out of the ground so that the operator will not have to lift the breaker and it will not get stuck.

**Low angle support**
During lower angle work the backwards rolling legs supports the weight of the breaker making it easy for the operator to perform this type of work.
**Mockups Concept Exploration**

**Movability**
The movement during transport feels very easy and free. The same principle like a wheel barrel.

**Chamfer (top)**
With the chamfer on the top towards the user there are no pointing edges and the user can stand closer to the breaker for better posture.

**Posture (high handle bar)**
The handle bar feels good when you push down because you don’t have to bend as much in the back but pulling up you have to lift mostly with your shoulders.

**No stand**
The operator have to put the product down on the ground when taking a break.
Mockups Concept Exploration

03
Mockup

- **Sideways movement**
  The sideways movement makes it very easy to reposition the chisel.

- **Fixed handle height**
  Due to the chisel feed the handles stay in the same height during breaking.
**Mockups Concept Exploration**

**Dust prevention**
A tube very close to the end of the chisel, with air suction, makes the dust prevention very efficient.

**Low angle support**
In lower angles the breaker tends to “run away” from the user, which makes it quite unergonomic for the back.

**Breaker depth and edge**
The mockup feels like it is too deep and also the more sharp edge doesn’t feel very pleasant against the body.

**No stand**
The operator have to put the product down on the ground when taking a break.
“It is a good idea, because the breakers are rather heavy. When you carry them around for a whole day you get extremely tired” [Alex/ Brokk Operator]
+ 1-wheel
   Easy movement and light construction.

+ Sideway motion
   Wheel makes it easy. Alternative pivoting motion with wheel locked in moved out position.

+ Backwards moving wheel
   Feels "more free", supports weight better, and makes it easy to position chisel and get it loose with tilting movements.

+ Dust Prevention
   Increasing need. Believe most in water spray nozzle focused on source but also open to vacuum function.

+ Wheel size
   Wheel size is perfect for purpose. A smaller wheel would get stuck in debris.

+ Pipe/Cable scanning
   Yes, that's a problem and especially the water pipes. Interface/led indication on top (green/red).

+ Wheel detaching
   Perfect for situations where the wheel is in the way. Also this aligns with AC's strategy of having the wheel as an accessory.

   - Chisel feed
     Don't want chisel feed and fixed handle height because they believe they will loose the ability to push down the tool.

   - Prop stand
     Not necessary! Use it in beginning but then get tired of it and just lie the breaker down.

- Extra mid-handle
  Keep it simple. A T-handle would be enough.

(i) Simple or concealed wheel functionality
   Dust and concrete will destroy it.

(i) Handle in (lower) front
   For lifting in and out of vehicle, windows...

(i) Narrow, rugged and simple T-handle
   If it sticks out it will break. U-shaped bar makes it stronger. No D-handle because it's easier to stand straight.

(i) Keep it simple and durable
   People will throw it and handle it rough.
MOCKUPS EVALUATION (PERSONAL)

01
+ Low angle support (weight)
+ Transport
+ Stand alone
  - Chisel position
  - Sideways workflow
  - Static movement
  - Wide body (hit legs)

02
+ Chamfer (top)
+ Movability
+ Lifting support
+ Low angle support
  - Sideways workflow
  - Posture
  - No stand

03
+ Fixed Handle height (Adjustable)
+ Sideways movement
+ Dust prevention
  - Low angle support
  - Depth + Edge
  - No stand
IDEATION

INITIAL FUNCTIONALITY

CONCLUSION

CONTROLS
- Breaking On/Off
- Wheel Up/Down
- Wheel Front/Side (?)
- Working lights On/Off
- Pipe Scan On/Off
- Pipe detection Indication
- Handle height adjustment

SMART BREAKING
- Slow start
- Feedforce = Power adjust
- Frequency/Force adjust to material

USER ID
- Remember height settings
- Vibration log
Aiming for cheap and less mechanical complex solutions...
01 **Self-stabilizing wheel**

A principle like the front wheel of a bike. The offset axis combined with the weight makes the wheel want to move towards the center, stabilizing it after the sideways movement...
Compass pivoting

A simple and ergonomic way to take small sideways steps, not lifting the weight of the ground, and an effortless way of repositioning the chisel with high precision.
IDEATION  SIDEWAYS MOVEMENT
A series of mockups were created to test the ergonomics of different types of handles during lifting, pressing and low angle breaking...
IDEATION  HANDLE ERGONOMICS

weight  23 kg

pressure  17 kg
01 T-Handle / Simple

A simple and overall ergonomic handle, used by the most breakers today.

PRESSING ●●●○
LIFTING ●●○○
LOW ANGLE ●●●●●
D-handle / Multi-grip

Fixed wrist angles, bad hand positioning and small hand contact areas, results in poor ergonomics.

PRESSING ●●●●
LIFTING ●●●●
LOW ANGLE ●●●●●
IDEATION HANDLE ERGONOMICS
T-Handle / Bike

Compared to the traditional T-handle design the small rotation in the wrist results in an overall more natural hand positioning in the grips.

- PRESSING
- LIFTING
- LOW ANGLE
IDEATION HANDLE ERGONOMICS
Test conclusion

A T-handle promotes better ergonomics than a D-handle for the tested types of movements. The ‘bike’ handle proved slightly better than the ‘traditional’ handle, allowing the arm/wrist to twist slightly outwards — a more natural position.

01 T-Handle / Traditional

02 D-Handle / Multi-grip

03 T-Handle / Bike
D-Handle / Transport

It is very useful for lifting the breaker in a horizontal positioning, but the centered weight puts all the strain on 1 arm. Also the handle block the view in certain angles.
Designing for different body dimensions...
People Size Pro 2008 / Ergonomic Database

AVG handle height: 89 cm / Range 1st - 99th: ± 12,1 cm

The average hand height for male users (dimension percentile 1st - 99th) is 76 cm ± 12,1 cm — a range of 24,2 cm from 63.9 - 88.1 if the handle should fit everyone. A distance of 13 cm is added as the approximate difference between hand resting height and handle gripping height — making the average gripping height 89 cm, which is the same as the handle height of the existing breakers (see illustrations below).
**IDEATION**  DUST CONTROL — CHOSEN TECHNOLOGY

**Water Spray** / A simple and efficient solution, but not possible in all locations. Need extra hose connection...

- 70-90% DUST REDUCTION
- WATER HOSE CONNECTION
- 21 LITERS/HOUR

**Air Vacuum** / Flexible solution (no extra hose). Increases complexity and cost...

- INCOVENIENT (VISIBILITY + HOSE)
- IMPROVED VISIBILITY...
- TECH: DYSON VACUUM
IDEATION  FUNCTIONS & ACTIONS (REVISED)

- **Pipe Detection indication**
  Led light indicating when pipes or electric cords/cables are detected

- **Vibration Sensors**
  User specific vibration feedback/log (requires user “login”)

- **Height Adjustment**
  Operator login = automatic handle height adjustment

- **Smart Breaking**
  1) Slow start. 2) Feeding force adjusts the breaking force. 3) Breaking force/frequency adjusts to material properties

- **Powerful LEDs**
  Directed lights increases visibility. Turning on automatically when breaker is on

- **Sensor (Pipe detection)**
  Sensor becomes active when the breaker is switched on/connected

- **Controls**
  Breaking and leg rotation actions are linked to motors controlling the forces with precision

- **User Login**
  User specific vibration feedback/log (requires user “login”)

- **Hose connection (On)**
  When the hose (energy source) is connected to the breaker it becomes active

- **Leg Rotation**
  Sensitive and precise control over the operator movements and the amount of weight support needed for certain angles and actions

- **Water Control***
  Physical control by water connection
# IDEATION: Power Source

## 2025

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<thead>
<tr>
<th>Power Source</th>
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<tbody>
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- Chosen features of the future
How might we get power to electrical components in the breaker?

**TURBINE**

During breaking a turbine generates electricity which charges an internal battery.

- Simple, cheap, with no change to compressors or powerpacks.
- Is the power generated enough?

**BATTERY PACK**

Exchangeable battery packs are swapped between compressor and breaker.

- New type of compressor with integrated battery charging needs to be developed.
- Not a very convenient solution.

**ELECTRIC HOSE**

Electricity is integrated into the pneumatic and/or hydraulic hose.

- Simple solution with "unlimited" power and no concerns of flat batteries.
- Easily integrated in existing compressor and/or powerpack designs.
Engineering feedback: Thomas Lilja, AC Tools, Kalmar

**INVALID PRINCIPLE**
— Rotating arm

"The rotating principle will not work. A lot of rotating force are required and the wheel would get stuck in the debris while moving backwards."

**SOLUTION 01**
— Push-off tube

"A ‘push-off’ tube combined with the rotating arm, could work as an alternative solution, but the principle is rather complex."

**SOLUTION 02**
— Transversal movement

"A transversal movement would be the best. It’s simple and takes full advantage of the hydraulic force."

Chosen
Best Principle
IDEATION  HYDRAULIC PACKAGE

Hydraulic Package

Technical Drawings — Reference

Basic 3D package (Solid Works)
IDEATION  WHEEL CONFIGURATION

01 / Mono wheel
— Simple
— Hard to integrate visually
— Only frontal workflow

02 / Dual wheel
— Unnecessary complex
— Less freedom of movement
— Only frontal work

03 / Sideways wheel
— Simple
— ’Specialized’ functionality
— Optimized (sideways) workflow

Chosen
Best Principle
IDEATION  WHEEL ROTATION (TRANSPORT MODE)

01 / Chisel pivot
— Clean expression
— Complex mechanism
— Takes a lot space internal

02 / 'Ring' pivot
— Blocking chisel view
— Visually bulky
— Non-integrated

03 / 'Arm' pivot
— Separated functions
— Takes up more space
— Technical simplicity

Chosen
Best Principle
IDEATION  MOCKUP — TRANSVERSAL & SIDEWAYS WHEEL FUNCTION

Concept
Final

Weight + Feed Force (minimal)

Hydraulic ‘Push’
IDEATION  
MOCKUP — TRANSVERSAL & SIDEWAYS WHEEL FUNCTION

Sideways Workflow

Frontal Transport

Wheel Rotation
Test conclusion

When the hose point backwards, it limits the movement of the user since it is in the way of the legs. It did not seem like there is any big difference between high and low side position, but this test was done without pneumatic pressure. The rigidity may affect the maneuverability.
DESIGN LANGUAGE
User Centered
— Comfort, Safety, Ergonomics

Performance Focused
— Muscle, Brains, Efficiency

Reliability Driven
— Durability, Honesty, Service ability

Solid Grey / Base and solid ground, protective.
Sophisticated Yellow / Housing for performance equipment.
Component Black / Components, wheels and hydraulics.
Value-adding Silver / Metal components, handles, protective bars.

Pure geometric with cut corners
Dynamic tapered shapes
DESIGN LANGUAGE  ATLAS COPCO / PROFESSIONAL TOOLS

Main Logo
(High Visibility)

3 Step Surface

Fastening Screws

Graphics

'Rewrapper'

Back Logo

Grill

Yellow Logo

Yellow Detail

'Recessed Area'

‘Wrapper’

Yellow Logo

Grill

Yellow Detail

‘Wrapper’

‘Backbone’

Back Logo
INSPIRATION FROM THE PAST

[Images of various handheld demolition tools]
FORM DEVELOPMENT
The form development phase was initiated with a 2-day visit/workshop at Atlas Copco for inspiration and guidance...
PART 01 / Initial thumbnail exploration, Atlas Copco form language
PART 02 / Simplifying shapes, integrating handle
FORM DEVELOPMENT  
TRANSVERSAL MOVEMENT
FORM DEVELOPMENT  WHAT SIZE?

Size = Power source  /  How compact can it be?
FORM DEVELOPMENT

COMPACT SHAPE — DETAILING
FORM DEVELOPMENT  COMPACT SHAPE — KEY SKETCH
Cardboard Mockups
— Evaluating shape and dimensions in 1:1...
FORM DEVELOPMENT  SIMPLE & ICONIC — KEY SKETCH
FORM DEVELOPMENT  INITIAL CAD & FOAM MOCKUPS
DESIGN
THE FUTURE OF HANDHELD DEMOLITION / MFA ADVANCED PRODUCT DESIGN 2013 / PHILIP NORDMAND ANDERSEN
DESIGN SIMPLE & ICONIC
DESIGN  MOBILITY & PRECISION

THE FUTURE OF HANDHELD DEMOLITION  /  MFA ADVANCED PRODUCT DESIGN 2013  /  PHILIP NORDMANN ANDERSEN
Integrated smart sensors, makes it easy to maneuver AIR-X1 — it becomes an extension of the body's natural movements...
Design handle controls

- Wheel Lift
- Light
- Water Spray
DESIGN DUST CONTROL & WORK LIGHT
Electricity
Water
Air
DESIGN CHISEL RELEASE & REST DETAIL
MODEL BUILDING
THE FUTURE OF HANDHELD DEMOLITION

MFA ADVANCED PRODUCT DESIGN 2013 / PHILIP NORDMAND ANDERSEN
THE FUTURE OF HANDHELD DEMOLITION

PHILIP NORDMAND ANDERSEN
EXHIBITION & MODEL
BREAKING SMART

The future of hand-held demolition

AIR X1 is a new ergonomic ‘breaker’, with a unique supportive wheel design — keeping professional construction workers healthy and productive.

PURPOSE

Sports and games are the most common type of injury in the construction industry. The ‘breaker’ tool forces the worker to direct a horizontal weight on his body, which is often fatal. The risk of an injury to a heavy load will result in bruises, fractures, and even fatalities. The wheel design adds support, making the tool easier and safer to use.

NETA:

The wheel design is an innovation that improves the tool's usability. The wheel design can be used to navigate the tool on a flat surface and to support the tool's weight. The wheel design is also ergonomic, making it easier to hold and use the tool.

MFA ADVANCED PRODUCT DESIGN 2013 / PHILIP NORDMAND ANDERSEN
REFLECTION
"A major reason for choosing this project was the fact that I could develop the design closely together with professional users" [Philip Nordmand / Product Designer]
AFTER 2 YEARS OF INTERNSHIPS I was really looking forward to going back to school and starting my final project. Being able to explore without the natural limitations of the industry and immersing myself in a topic with emphasis on the parts of the design process was really interesting and fun. It was actually really hard finding a good and relevant topic because there were so many things that needed to be considered. I looked a lot at what other APD students had designed in previous years and picked out the projects I wished that I had done. The year before my own degree there were 3 projects in particular that I thought were inspiring, two of which were Atlas Copco (AC) projects. Actually I was doing my internship with AC during those projects and I got to be a part of the ideation process and also act as a tutor in developing product character. The good experience from my internship combined with the fact that AC have a lot of experience with degree students, providing a lot of freedom and providing good financial support, encouraged me to decide on AC as a collaboration partner.

The past couple of years have seen a lot of degree projects with big machines and several of them have been AC. I didn't want to be yet 'another' machine from Umeå and decided to do something different. When I came up with the idea of designing a breaker all the pieces fell into place. Of course I was still in doubt if it was the right project but I just had to take the decision and go for it. A major reason for choosing this project was the fact that I could develop the design closely together with professional users — utilizing a user centric design approach that would give me valuable insights during research, ideation and concept refinement. Also the ergonomic aspect and size of the design would allow me to work with a lot of physical mockups, getting away from the screen and spending time in the workshop. Furthermore I thought it would be great to end up with a big 1:1 presentation model, since I feel like I had neglected this skill a bit during my studies and this would be my last chance to do this and utilize the great UID workshop facilities.

Some of my doubts regarding the project was that focusing at 25-30kg breakers would be too narrow a scope for this type of project and I needed to find a more holistic approach. After having gone through the process and followed the processes of my classmates with very different types of projects I must say that the overall impression is that a more focused project is the better choice. Even though the degree project is the longest project you will get in school, the time schedule is still very tight and very intense. Some of my classmates that had a very open approach found themselves after months still trying to define exactly the subject area and what to design. As a student you don't want to put yourself in that situation in your final project and realistically, the more focused and defined your project is from the beginning the better.

Design Process

During research I fell into a time trap despite the fact that I had already been warned about it. It was extremely time consuming to find users that wanted to participate in interviews and observations. Also a fact about my target group of labor workers was that some of them could not, would not, or were simply embarrassed to talk english and they would just hang up the phone. Luckily my mentor from Atlas Copco had time to call some of them for me to explain the situation better in Swedish. I ended up spending weeks calling around and my schedule got quite delayed, which in the end gave me almost no time to process the research information and document it in the manner that I had planned for, like creating a video of the footage I did.

For my initial ideation I hosted a 1 day workshop at the Atlas Copco Industrial Design Competence Center in Örebro. I had carefully planned everything and made sure that the process was both fun but also forced some of the rather experienced designers out of their comfort zone. The ideation method of building on each others ideas was interesting and I think it forced people to create more innovative ideas. It was however also time consuming and we ended up brainstorming on only half of the questions that was intended. This wasn't really a problem since some of the questions were in similar contexts and there would definitely have been some overlapping in terms of ideas. I think for another workshop I would create less focus and look at very different questions. Using the AC team of experts, all with industrial design backgrounds, created a high output of great quality and very relevant ideas and despite not planning to do a workshop at school with fellow students I realized that I actually didn’t needed it.

My main contact within AC for this project was my mentor from the ‘Industrial Design Competence Center’, a former UID student, but I also had a lot of meetings with two design engineers from the AC ‘Construction Tools’ department — experts in the field that had in fact designed many of the existing breakers on the market. My mentor, having the same
edimentary background as me, fully understood my project but the design engineers occasionally had a difficult following me. Also they were being very polite and possibly holding back on criticizing some of my ideas. The result was that in a side remark in an email one of the design engineers mentioned that he didn’t think that the functional principle my design was based on would actually work, which was great feedback, but it was also way too late and it cost me a lot of time. So you need to make sure that people understand that they should say what they think, without holding back. Another small takeaway that I learned was to use the project time frame to help keep an open mind, when I was presenting ideas. If for instance the design engineers started to question suggested technologies I would remind them that the product was to be launched in 2025, more than 10 years in the future. Everything needed to be considered to create an innovative approach.

During the development of the design language my AC mentor insisted that I aligned the product expression with their new products, so that they could be exhibited together at fairs around the world appearing as a product family. Naturally I insisted that I aligned the product expression with their new AC heritage, making the products less approachable and less elements, it was moving quite far from the form of the original design. I really changed much since they were invented more than 10 years ago. In my early research I realized that heavy breakers haven’t really changed much since they were invented more than a decade ago, the biggest innovation being the recently developed vibro-reduced models. The spring loaded handles absorbing the vibration was a small brilliant upgrade that have made a big difference in the industry. All the brands are now promoting their vibro-reduced models and they have become the new market standard. This shows a mindset change in the construction industry — the focus shifting from tool performance to worker health and safety. This is why I think there is a big market opportunity for ideas like AIR-X1, rethinking the entire tool from a user perspective, creating a totally different product experience from the existing breakers of today, allowing construction workers to demolish horizontal surfaces in an ergonomic, safe, and effortless way.

The idea with the wheel is quite simple and it makes me wonder why it hasn’t been done before. Maybe some company have played with the idea, but it would probably require quite a big investment to develop into a market ready solution. Also a tool like this will be more expensive to buy/rent than the existing, but my guess is that in the end the pros will outweigh the cons, since there is so much to gain from workers staying healthy — reducing injuries, sick leave, and early retirement from wearing the body down. Also the task now require less strength which means that workers will be able to work longer with less physical fatigue, maybe even opening the opportunity for new type of workers that doesn’t need to have the same strength as the workers of today? I know for a fact that AC realized the real potential in the idea because at some point there was talk about applying for a patent, but in the end it didn’t happen since the team at the Construction Tools department decided not to go through with it. Of course a
patent would have protected the idea better, but even without it I think an innovative project like this could put AC in a strong market position. I’m not sure if they are going to continue with the project internally since I haven’t heard anything, but it would be a dream coming true to see it become reality some day.

Even though AIR-X1 never becomes a reality it still has a lot of value for AC — both internally and externally. Internally these type of projects are used as role models or so called hero projects. They create excitement within the business and also align people towards a common goal for the future. They also promotes the Industrial Design Competence Center, showing that their capabilities goes beyond styling and changing the outer surfaces which outlines their belief in designing visionary and innovative solutions for an entire product or range of products, potentially being brought into projects much earlier than what is generally the case today. Externally they can use it for clients and fairs, branding AC as an innovative and forward thinking business.

If I had more time to work on the design I would have worked more on the controls around the handles and how to indicate the different functions better. For now the argument is that the tool is for professional users and since the functionality is not that complex the user would be able to memorize it, but I think it’s never a good idea to just say “read the manual” and expect users to be able to use the product unless it’s very intuitive. The idea would be to implement some icons on the handles, which I also explored but I couldn’t make work within the time constraints and I would rather leave this detail out of the project rather than suggesting something only partly solved.

It would also have been interesting to go a bit more in depth with the app and how this connection with the tool could be beneficial for different types of users. In the project so far I only focused on primary users but what if there was an app for services as well, telling the technician about possible errors?

There is many possibilities, and in I would not have time to explore them all, which is why setting limitations is so important. What do you want to solve and what don’t you want to solve? Sometimes it makes sense to give a qualified suggestion as a placeholder, without going too much into depth if it strengthens the main idea. Like for instance I added the integrated water spray solution to the product and suggested a new type of powersource hose combining pressurized air (or oil) with water and electricity, without going in depth with it. All in all I think I achieved a good balance between time available and the final outcome.
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APPENDIX
“We don't just work 15 minutes an hour, then it would take a hole year to get the job done”

NAME: PETER
AGE: UNKNOWN
OCCUPATION: WORKER
EXPERIENCE: 6 MONTHS

- He doesn’t use the Hilti 1000 that often since he is mostly drilling holes. The last time, before he was drilling yesterday, was like a month ago.
- (3:40) Can you feel the work in the body sometimes? “Oh yeah, it’s paid training”
- “I still feel it in the shoulders from yesterday... That I worked out a little bit”
- He was using it all day (maybe 4-5 hours). Sometimes he was working with it for 2 hours before taking a real break. Sometimes he will take like 3-4 minutes.
- “You can work with it 15 min each hour and then you need a 45 min break, but that never happens [...] You work with it to the job is done!” (9:50)
- “We don’t just work 15 minutes an hour, then it would take a hole year to get the job done” (10:35)

“The floor is pretty easy for the shoulders compared with the walls”

- He gets most tired from working with walls. “The floor is pretty easy... For the shoulders [compared to the walls]”
- Is it the Brokk 40 too heavy for the scaffold? “No, but it’s complicated... To get it up”
- Do you do the crowbar move? “Oh yeah, you have to do that sometimes to break it off”
- He thinks it’s a good idea with an autonomous machine doing the floor work and then he can go do something else.
“Nobody cares about this 45 minutes, you use the machine until the work is done — but it's always a free choice”

NAME MARKUS
AGE 33
OCCUPATION  MANAGER / CEO
EXPERIENCE 6 YEARS +

• "If you look at the time you use the machine it's mostly on the floors, not so much on the walls"
• "The Hilti 3000 is very good on the floor, but it's pretty heavy [...] It's a good machine for the right jobs (not walls)" (3:20)
• How is the heaviness affecting you? "You get tired! You don't get the strength to work so long" (3:30)
• Mostly tired in the arms
• They use strength just to support the breaker. "If you just hit straight down nothing happens. The chisels are often angled down, because then you get a better break in the concrete" — "if you just break down maybe you will get stuck" — "It's heavier to use [when breaking on an angle] because it doesn't stand on it's own, you have to hold it" (4:20)
• "The trolleys are too clumsy, because you have to move a lot, you hit it in different angles, you break, and the machine is often moving all over the place [...] if you have it on wheels it's not so effective. If you are going to hit one point. It's okay but the reality is not like that" (5:30).

“You have to move the breaker a lot to hit the concrete from different angles”

• Agreed that they are sacrificing ergonomics for efficiency.
• Recognize crowbar movement? "Yes of course, you always try to break as big pieces as possible" [...] "The bigger pieces the better, because then you get the work quicker done" that's why they use it as a crowbar
• "When working with floors you often try to go under the floor and break it up, then you use your shoulders a lot" (8:00)
• "The bigger pieces the better because then you get the work quicker done"
• It's not so common to break a whole floor like 20 cm thickness, often it's bumps (spilled concrete) that you make
"If you look at the time you use the machine it's mostly on the floors, not so much on the walls"

"When working with floors you often try to go under and break it up, then you use your shoulders a lot"

"The Hilti 3000 is very good on the floor, but it's pretty heavy [...] It's a good machine for the right jobs (not walls)" (3:20)

- If you hit straight down nothing happens. The chisels are often angled down, because then you get a better break in the concrete” — "if you just break down maybe you will get stuck” — “It's heavier to use” [when breaking on an angle] because it doesn't stand on it's own, you have to hold it

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"If you just hit straight down nothing happens. The chisels are often angled down, because then you get a better break in the concrete”

- The Hilti 3000 is very good on the floor, but it's pretty heavy [...] It's a good machine for the right jobs (not walls)" (3:20)
- Most workers are moving all over the place [...] if you have it on wheels it's not so effective. If you are going to hit one point. It's okay but the reality is not like that” (5:30)
- Agreed that they are sacrificing ergonomics for efficiency.

- Recognize crowbar movement? "Yes of course, you always try to break as big pieces as possible” [...] "The bigger pieces the better, because then you get the work quicker done” that's why they use it as a crowbar
- "When working with floors you often try to go under the floor and break it up, then you use your shoulders a lot” (8:00)
- "The bigger pieces the better because then you get the work quicker done"

- It's not so common to break a whole floor like 20 cm thickness, often it's bumps (spilled concrete) that you make smooth, tiles
- The most common chisel is the "flat mejsel". The pointy one have a tendency to just go down. The wider ones are hard to get into the surface and those are used for tiles and the bumps.

- Chisels are stored in the case. Sometimes they transport the breakers in the case or they just carry it. Depends. Don't use the transport trolley.

- Do you consider the breakers the hardest tool to use? "Yeah I think so, because that tool affects your body most, and it affects your hands — many have problems, they get white hands” but they don't have anyone who has it. He heard about it... (13:22)

- The builders putting concrete on the floors often have problems with HAVS because they use the breakers so often to remove the concrete that get outside, making the floor smooth/straight.

- No one in Markus company has any problems with HAVS because they often use the robots. They only use the Hilti's when they can't get there with the robots.

- The breaking I saw in the elevator shaft was a good example of a place where they couldn't use a robot. It would take too much time and it would be impossible to get the robot on the scaffold.

- It's never so much time they use the Hilti's. Mostly bumps.
- You can use the breakers in "different kind of steps. First you can use it for about 45 min a day. If you have been to the doctor and get an examination then you can use it for 120 min or something and then you have to stop. You can never use it longer. But when they are 2 people they change often so you don't get tired and you wont get any problems with your arms or hands” (15:44)

- Peter working 4 hours on a day? "Yeah it's often like that. It's about getting the work done, nobody cares about this 45 minutes, you use the machine until the work is done — but it's always a free choice. There is regulations... Kind of regulations... How long, but [...] many that works with these machines know these time limits, but it's more about doing the work. But then they [only] use the machine maybe one time in 2 weeks. It would be different if you use it every day then this time limit would be very important to follow” (16:30)

- Dust a problem. "Yeah you should use a mask". If you are in an apartment you use air-cleaners. They put plastic on the doors and it sucks out the dust. "If you are in a sensitive place, also in construction sites then we use air-cleaners".

- With the robots they often use water-mist to take down the dust. It doesn't create problems because it doesn't matter if the bare floors get a little bit wet. The concrete sucks up the water too.

- "You can use dust machines on the breakers, but it's not used so much because then you have to have a vacuum
cleaner connected and you have to have the hose” — “it has never been used before and that’s the reason” (20:00)

• How long does it take to set up the dust suction? “30 min maybe [...] It’s not so complicated” (21:00)

• What if the breakers was sucking in the dust? “Could be good but you always have to connect something to it, otherwise the machine gets too heavy. You can’t have like a holder on the machine” (21:30)

“If you use hydraulic [breakers] then you need a power pack and it’s too clumsy and too heavy to bring around”

• Why don’t you use hydraulic/pneumatic breakers? “If you use hydraulic [breakers] then you need a power pack and it’s too clumsy and too heavy to bring around [...] you need the hose for the oil to circulate, it’s a little bit clumsy to have that and also it’s more heavy”

• Sometimes cables/electric cords get damaged. “The biggest problem is when you hit a water pipe in the floor. Often when you’re going to take away — first there is the concrete floor, then there is the “kage (cookie)” and often they put the pipes in it — then you start breaking and then it gets wet [...] Maybe its like 10 times a year when you don’t know what you are going to hit” (23:00)

• They have a Brokk 40? “We use that a lot instead of the Hilti 1000, because it’s small, you get in with it. It’s like with the trolley you can’t bend the chisel on the robot, but it’s stronger and you can use it for a whole day without getting tired, so it’s a good tool. But it’s pretty weak the 40 it’s not so much [power] to break with. Compared to the Hilti 1000 the power of the Brokk 40 is pretty much the same, it’s just the time you can use it that is different. A man don’t have the power to stand with a breaker all day” (24:30)

• Is it more effective to use a hand tool? “It depends on what you are going to break. If you are going to break a concrete cookie, if it’s a big floor, the Brokk’s are very good because then you can use it a lot. But if it’s small stuff like in the shower where we break around the walls [...] the Brokk is not that good because you have to be more precise (25:30). Robots are good in big areas and hand tools in more tight spaces.

• Could you imagine a robot being even smaller than a Brokk 40? “Yeah why not, it’s just that you have to get the power in it too. You can’t use something with less power than a Brokk 40, nothing would happen. The problem is to have the robot small and still have the strength to break” (26:50)

• Would you see the value in a machine that is only for floors but really effective at it and then being more compact? “I don’t think it’s possible to make, because you still need to have this arm and you still have to break with it, like the hand machines (can’t just go straight down, because nothing will happen), but if it’s possible to use it, yeah why not?” (27:30)

• What is the size of the Brokk 40? It’s pretty small. It’s like 10 times a year when you don’t know what you are going to hit” (23:00)

“The problem is to have the robot small and still have the strength to break”

• How important is it that it’s compact? “It depends what you are going to break. If it’s a big wall then it doesn’t have to be so compact, but if you want to get into an apartment with 90 cm door then you need a little machine”. (28:45) The size of the space and the access to the space!

• They have never used a Brokk in an apartment, then they use the TE-1000. The Brokk takes up too much space in a bathroom and “you have to be pretty steady on your hands so you don’t break the toilet or the stuff in there. You can get some marks from the tires too” (29:45)

• Could you imagine a robot that you control with your arms/body but the movements would be really easy like the power-steering in a car? “It’s hightech stuff. Maybe I don’t know. It’s hard to say when you don’t really see it in front of you. It’s hard to imagine how it would work in the field but...?”

“The our body is working harder for the work we have instead of sitting on a chair, typing on a computer, but if you do this work right, you get a lot of training, which is good”

• Autonomous robots? New concrete walls, the saws have that. You put in how deep and how long, “It’s more effective because you can do different kind of stuff” (34:30)

• Body wears out before time? “Your body is working harder for the work we have instead of sitting on a chair, typing on a computer, but if you do this work right, you get a lot of training, which is good” (35:30).
“I hate working with jackhammers! Maybe for 1 hour because it's good exercise, but I'm more of a robot kind of guy"

NAME ALEX  
AGE 21  
OCCUPATION WORKER (ROBOTS)  
EXPERIENCE 2.5 YEARS

• “It’s hard work you know”
• “It’s difficult to work with it (TE 1000) over your head, sometimes you have to do that because the smaller ones are not powerful enough”
• “The 3000 is too big to do anything above the waist, it’s only for the ground”
• Autonomous? “I believe that, you don’t have the same type of control if you just type something in and then it should do that. When you are standing there you can see exactly what is happening and you can do as you please. You know what kind of result you get, so I’m not all for fully automatic” (1:00)
• What about just for the floors? “Yeah, that would be awesome because we have hundreds of tons of floor down stairs, if you just type something in and it goes from wall to wall like a robotic lawn mower, but I think it’s a long way there…. I don’t know how far they are with technology” (1:40)
• He doesn’t use the 1000 that often, since he is mostly driving robots, but around 1-2 times a week for like 2-3 hours.
• Do you feel it in the body after using it? “No… No, you can’t use it all the time without stopping because you stop for a moment to look at the result for what you have done, and
then your body and hands get to rest and then you go again, so it’s maybe only like 5-6 times I have really felt it when I came home since I started 2,5 years ago. That’s mostly because I have a hand injury, I cut off some nerves”

“Since I started 2,5 years ago, it’s maybe only like 5-6 times I have really felt it in my body when I came home”

• “I have tried so older machines, the 905, and the difference is significant! Amazing actually! When you use the 905 it’s like it slaps back in you hand more than the floor, but in these new machines you barely feel anything”
• “Then you have the small machines with small vibrations and they are actually the ones who are more dangerous, because you don’t think of it that much [...] but actually we are not using them that much, just for small stuff”

• “Here we have 2 robots all day, all the time, sometimes we use handheld tools over the day, but I think I can count on one hand the days where we haven’t used the robot”

• Could you imagine a robot smaller than the Brokk 40? “No, I could use small robots as well? The Brokk 40 is pretty much the same power as the TE 1000” (6:40)

• “You have the companies that produce the hammers, we only use Atlas Copco and they are the best in the business. I believe if they could go smaller they would and maybe in some years they can, but right now the smallest hammer has no power” (8:00)

• In private homes it’s mostly bathrooms, not big floors. He thinks that autonomous floor robots would be better in big spaces like the one they are currently working in, but it’s not very common for Umeå. “If you look at it world-wide it’s a pretty good idea actually” (11:00)

“[For hammers] we only use atlas Copco and they are the best in the business! If they could go smaller they would”

• The robots are very versatile. Beside breaking they can lift, dig, saw. “The versatility is important, but if you have a lot of money [a more specialized machine] is great because you save a lot of time” (15:30)

• Power-steering? “For me the small sticks are perfect because you have the sensitivity, you can do very small movements, if you get bigger maybe it gets more ’twitchy?’ (17:45). (He has a hard time imagining how the ”power steering” would be like, but he will rule out that it could actually work. Actually I’m not quite sure he understands what I’m talking about)

• “Since I started 2,5 years ago, it’s maybe only like 5-6 times I have really felt it in my body when I came home”

• “I have tried so older hand tools and the difference is significant... Amazing actually!”

• The size is good you can climb stairs with it so it’s perfect, but the power is too little. The Brokk 50 is the same size but power is a gigantic difference. If you go any smaller it wouldn’t be useful because the hammer on the robot has to have some effect and I believe if you make it smaller you loose the effect. Maybe if they develop very small hammers you could use small robots as well? The Brokk 40 is pretty much the same power as the TE 1000” (6:40)

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• “The downside [of the Brokk 330] is that it’s very slow, runs on electricity and you have to move it with a truck. You can’t move it on a simple trailer. It’s too heavy (4 t vehicle + 0,8 t scissor). The power of the Brokk 330 and the 800 is the same. The only difference is that the 800 can move further” (1:15)

• You like working with the Brokk 330? “Yeah I love it! You feel so powerful when you do this” (4:30)

• You like working with the Hilti 1000? ’I hate it! Maybe for 1 hour, because it’s good to get the exercise, but I’m more of a robot kind of guy’ (4:45)

• Controlling the robot: “After a few hours you get the hang of it but it’s harder than it looks actually. The Brokk 330 is actually really good, it’s not so fast in the movements, the smaller robots are faster in the movements, so you have to have more precision. So, it’s actually easier to drive a big robot than it is to drive a small one” (5:00). You can adjust the speed of the movements but the hammer slows down as well so you wont get the same effect.

“"The versatility is important, but if you have a lot of money [an autonomous more specialized machine] is great because you save a lot of time”
“Hilti are the best at making low vibration tools. They are very good! You can use the TE-1000 longer than any of the similar tools from the other brands”

NAME KENNETH
AGE UNKNOWN
OCCUPATION REPAIR SERVICE
EXPERIENCE 28 YEARS

- Combi machine with drill and hammer.
- Have the tools changed over the years? "Yes, this TE-1000 is a very good tool. Hilti is the best at making low vibration tools. They are very skilled! You can use this tool longer than with the other brands"
- The micro filter in the vacuum cleaner lets out 99.97% clean air into the room. It will keep the worker safe from asbestos, silica etc.
- Many people rent air-cleaners
- Low vibration handle flexible rubber joint
- Is hose in the way? "The most times you are on one spot like in the bathroom working on the drain"
- 99% of the people that rent tools/machines are professionals
“The companies want it to be more ergonomic, so it has to be more ergonomic. They don’t want their guys to retire 5 years early, so of course they want their workers to be healthy. By that using good tools”

NAME: JOHAN
AGE: 21
OCCUPATION: SALES / EVERYDAY BUSINESS
EXPERIENCE: 1.5 YEARS

- Who is renting the machines? “From the big businesses that run through out Sweden to your local business guy that wants to do something at home. It’s mostly professionals, I would say about 95%” (0:45)
- What are the TE-1000 used for? “It’s a pretty broad spread. I would say bathroom floors. That’s the most seen. (2:00)
- 2 guys used 1.5 weeks to carve out the floor in a big room. They were working all day every day. They where looking at a Brokk, but the price difference was pretty big and they found it too expensive (2:30)
- They have Hilti and Bosch. You have Atlas Copco? “I think there’s an old Cobra but we don’t sell them anymore. The old school guys still search for them. No one that want to follow the new certified rules rent them. The Cobras they didn’t check through I think — not here. I didn’t work here at the time when they had them but I know there was a lot about services on them, they break, they cost a lot of money, and the people renting them didn’t want to pay that much, so they skipped them. That’s the word I’ve heard” (4:45)
- The most popular brand is the Hilti? “The one that runs the most through the door here is the 1000. The people coming in
here they don't even say Hilti they just say 1000" (6:40)

- Other competitors that makes some good tools? "Yeah, “We had [a 3000] here for 2 weeks in the shop, showing it off. People were just laughing at it — there's no way we are taking that thing!”

Bosch... And Makita does some good stuff too. We got this deal with Hilti, they rent to pretty much all of Sweden, so we use it, and it works great for us" (7:00)

- "They pretty much take the 1000 even though they have a small plumbing because it runs faster, instead of standing there longer with a 300, or the 7 or 6. It’s mostly floor work, if they work in shoulder height they go down to like a 300 or 500" (7:34)

- They only have had 2 rents on the 3000. Why? "People don’t know that it even exists — bad marketing! On the other side there isn’t much work you need a 3000 for." (09:30) But it’s better for floors no? "Yeah, but it’s big! I think that’s the main problem. Just looking at it, people give up. They won’t even get it in the car. We had it here for 2 weeks in the shop, showing it off, people were just laughing at it — there’s no way we are taking that thing!” (9:40)

- "I don’t think that people that rents the 1000’s reflects much on what it can do to themselves. There’s a lot of young guys coming in 18-20, they just pick out the machine because that’s how you do it, they just do the work”

- What can happen to the body? "I’m not an expert but back problems arms sore, that kind of stuff. The most guys are professionals. They use them every day like 3 times in a week. We never hear any complaints. Never. Well sure, the private guys who have never used them before they would say "ah, my back is hurting’. I don’t think they are used to it. They just

“There’s a lot of machines and they all have the same problem — you can only it for at limited amount of time” search on the internet how to do it and they come here, but they don’t really know what to do with it. The big companies that rents them they have a pretty hard schedule to follow. They put the standards by themselves — you can only use this for 15 minutes. We also send notes with the tools going out

“The private guys who have never used the tools before would say "ah, my back is hurting” [...] They just search online how to do it and they come here, but they don’t really know how to use it”
on a daily basis, we write "effective work time expected 15 min" (12:15)

• "There's a lot of machines and they all have the same problem, you can only use it for a limited amount of time" (14:00)

• Any changes over the years? "I think that they have put the most energy in how to make the machines more effective and not so much the weight or something else. To make them pound harder" (18:00). And to be more gentle to the body? "No I don't think so! The 3000 is a little bit different, you got the handle that comes along — it's not stiff like the 1000, so I guess they are actually coming a bit on the way" (18:20)

• Will tools change in the future? "People put higher standards all the time, making it more ergonomic. The companies want it to be more ergonomic so it has to be more ergonomic. They don't want their guys to retire 5 years early, so of course they want their workers to be healthy" (19:30)

• Autonomous machines? "Yeah, it's definitely in the future. I know in Kiruna men are drilling like 1000 meters under ground with the drilling rigs, but now the run it from above the ground with remote" (21:30). "It seems like the future is going more towards autonomous machines, lifting the weight off the body" (27:00)

• Especially when there are water pipes, they need to go from different angles... They need to change angle. The thing that is hard about the Brokk robots is to do precision work, to control the drill like when you are actually holding it in your hand, which is one of the reasons why they are still using the hand tools"

• Opportunity? "I think you should look at the machines how they are now and see if you can make them lighter or somehow easier to use for the body. When they come here to rent they just want the simple tool, because it does the work and it's often just a 2 hour job. Don't make it too complicated! Keep some parts of what it actually is. You need to see what you are actually doing sometimes"

• Would people be willing to pay extra for enhanced ergonomics? "Yeah, definitely. I would say the big companies that puts the standards. If they come in here and they have to pick between a Hilti and another machine that does pretty much the same work, it's easier but costs more, they would definitely pick the one that costs more. They want their guys to be well"

“If they come in here and they have to pick between a Hilti and another machine that makes the work easier but cost more, they would pick the last. They want their guys to be healthy”
“I don't think you can work in this job until you are over 65. You will break your body before that”

--- Car trip 01 (voice)
- "We don't use the big breakers because it’s easier to use a Hilti, because we are going to break the floor into small pieces and a van with a vacuum cleaner will come and suck up the pieces"
- They use air cleaner/air cube and they a vacuum cleaner (not attached around the chisel)
- How long can you work with the Hilti? "I have no clue"
- How long do you work with it? "All day, but usually we are 2 so we can shift. Normally we get 1 or 2 day jobs. Small jobs. We only work with water damage, which is usually at a regular persons home"
- “Sometimes, working in bigger spaces, we have a demolition robot but usually just have the one you hold in your hands and you stand on your knees"
- Use gloves to take away some of the vibrations
- Like the work? "I actually like it. Most days. Some days are really shit days" (He doesn't like removing fungus in tight spaces)

“Sometimes, working in bigger spaces, we have a demolition robot but usually just have the one you hold in your hands and you stand on your knees”
Times they just sand or put on heat fans to get the water out of the floor, today we are going to remove the whole floor.

“Sometimes they just sand or put on heat fans to get the water out of the floor, today we are going to remove the whole floor.”

“The work always takes more time than they want it to be”

“It’s a busy period now for us when the ice/snow starts melting it’s going through the ceiling. That’s on top of all the normal water damages that come. Last month I did 219 hours!”

“Many places they work from 9-16, Monday to Friday, but they don’t want us to make any noise so we can only do it in the evenings and on the weekends. Then we work 7-16 and then go there afterwards”

“We have a very bad salary. We don’t make much money on this, so we are happy for every hour we get. We are in a different union than the carpenters”

“I wish I had the energy and the brain to study, but I just don’t know what I want to be”

“Car trip 02 (video)”

“I think the heavy machine will be hard to use if you have pipes in the concrete, because you have to be very sensitive to know where the pipe is and that machine is not so sensitive”

“You have to put a lot more pressure with the Hilti. You have to push it down to get the floor in pieces. You have to put some weight on it. The Dewalt is so heavy in itself so you don’t have to place some weight on it. It works by itself, but then I break your back when you have to lift it up”

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“Vibration feel? “It feels like when you leg is falling asleep. It’s not good. The heavy kinds of vibrations doesn’t feel as bad like with the multi cuter, a saw with 14000 RPM, if you do that one. And it’s hard to use vibration gloves on that one because it’s like having heat-gloves on. You have to be so sensitive” (4:30)

“You can work you back but you can’t do anything about the vibrations. You can wear gloves but you can’t do anything more, but you can work your back so it becomes strong before it breaks” (1:00)

“I think the heavy machine will be hard to use if you have pipes in the concrete, because you have to be very sensitive to know where the pipe is and that machine is not so sensitive [...] I think I will break the pipe if I hit it, as hard as it hits” (1:40)

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“The medium age in this company is like 24-25. It’s like 4 guys that are over 35” (14:45)

“Better tools in the future and manage job longer? “If you could have a robot doing what we are doing now, but you still have to hold it. At least now” (16:30)

— Fika break (video)

“In Sweden we call it Atenit, because it can last forever. It’s hard to operate several machines at one time because the fuse always goes” (8:30)

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not hazardous as long as it lays there. When you work on it cut in it like you do with the machines the fibres get out, and if you breathe them in they can cause lung cancer” (0:00)

• “It’s a good thing we wear this masks. Otherwise all this shit would be in my lungs. Some of those we work with don’t use these masks. They say they don’t like it.” (2:45)

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— Home trip (voice)

• Is the days always as tough? “No, but some days it can be tougher, like when you have to carry out the pieces in bags” (5:30)

• “You have to be iron man to have that machine” (7:00)

• “We are not allowed by regulation to use this Hilti more than 2,8 hours a day per person. I don’t know how much it is for the big one but lets say it’s 2 hours there. You can work that efficient for 2 hours, but not a whole day. If you go by the rules and have many people to pass it between, then I think it can be very efficient. If we are working longer than 0,8 hours with the Hilti a day, the company has to find other ways for us to do the job. We should use those machines as little as possible.”
“If we liked to we could take away wide weight [...] but then we would need to reduce the power because otherwise we need to push the machine much harder downwards [...] that is the main limitation for how much power we can put in the machine”

- Olof: “During the past 10 years we have worked quite a lot with vibration, trying to minimize that as much as possible. On all product sizes we have at least 2 different versions one with anti vibration system and one without. And quite surprisingly many prefer the non-antivibration and the reason is of course the cost for it, it’s cheaper and less complicated and it’s more likely that it will last longer before maintenance. There is less parts that can break” (4:45)
- Olof: “We have worked quite a lot with noise. There is something called the noise directive that is valid for all these type of machines that we are talking about now and it is based on the weight of the machine not the power of the
machine. Machines with higher weight can have a higher level of noise guarantee. There’s a special formula where you put the mass of the machine and it gives you the maximum sound level that machine are allowed to produce. In case you are above that level you are not allowed to sell that machine within the EU, one of our biggest markets, but maybe in the US or Africa” (5:50)

- Olof: “When it comes to vibration you are allowed to sell any machine with any vibration levels. The only thing is that you can’t use it for a long time, and I’m talking about the EU here. It’s up to the employer when he employ someone he must make sure that each and every employee is not getting vibration dose higher than a certain amount. So in case he has a machine that vibrates a lot, he can use it but only for a very short time, and if he have a machine with lower vibration he can work longer time. Maybe even up to 8 hours.

One of our worst machines you might even only be allowed “There is no certain limit it’s just allowed working time. That’s of course a sales argument from our side when we can give them machines with low vibrations, but surprisingly not many is caring about this” to use half an hour or something like that and then it’s up to the employee and the workers to share the work. Lets say you have 5 workers working just half an hour each and the rest of the day they need to do something else. So there is no certain limit it’s just allowed working time. That’s of course a sales argument from our side when we can give them machines with low vibrations, but surprisingly not many is caring about this.

The market is most caring about this is United Kingdom. They have a quite hard safety and health department that is really looking into this. (7:35) Thomas: “They are in the front line of ergonomics” (9:30)

- I thought Sweden was quite big in this field? Olof: “Yeah quite, but Sweden is not a very big market for us with this type of machines. In Sweden most of this work is happening with rig-mounted machines, which is not really the case to extend in United Kingdom. (9:35)

- Olof: “Dust is something that we haven’t worked a lot with but we believe that it will be one of the future challenges for us. We believe that will be more and more important” that extend in United Kingdom. (9:35)

- Olof: “Dust is something that we haven’t worked a lot with but we believe that it will be one of the future challenges for us. We believe that will be more and more important.” That has been a lot of attempts to solve this with type of vacuum cleaners. Something that you attach to the machine, some type of rubber unit surrounding the chisel and connected to a vacuum cleaner. From what we have seen so far many of these are not very efficient and they prevent the operator to do his work. Maybe they are blocking the view of the chisel so he can’t see where he’s working. Also they become very big and clumsy. Thomas: “On breakers it’s not so common to use dust collectors”. We haven’t really seen any good solutions to this but we believe that we have to look into this. For rock drills there’s a pot of this size. They are quite efficient for drilling. But even though they are working they haven’t been very big sellers. Another thing is that when they are using rig mounted attachments they have water sprinkle system attached to the machine body and they spray the area with water and also behind and beside the machine, binding the dust to the ground so to say. Thomas: “I think it can be a good solution”. There is no commercial success in any solution as far as we have seen” (10:20)

- Olof: “Many of these pneumatic breakers they are quite heavy, and they are heavy for one reason, that is when the power is high you need to push it downwards to work in a good way. To avoid having too much feed force from the operator we load the machine with weight. Thomas: “A normal operator can give 200 Newton or 20 kilos in feeding force, the rest we get from the weight in the machine”. If we liked to we could take away wide weight. We could make of plastic and make the wall thicknesses thinner etc., but then we would need to reduce the power because otherwise we need to push the machine much harder downwards. That is a problem. Thomas: “I would say that is the main limitation for how much power we can put in the machine”. We have seen solutions quite a numbers of years ago, ten years ago...
or something like that. Some English man found a solution where they placed a water tank on a machine, surrounding it, and then they have a tank beside and when you where pressing the trigger the water from the tank went into the machine, around it, so it become heavy and when you release the trigger all the water went back into the tank. All this water went back and forward all the time and of course when you have pneumatic power you could blow this water forwards and backwards quite easily. It was too complicated. Big tanks where needed, extra hoses. It's too clumsy.

Thomas: “That is one way of changing the weight of the machine having it heavy when you need it and light when you are lifting” (29:20)

- Lifting and repositioning becomes harder during the day.

“In many cases the one who buys it just want the lowest price. They don't care about the operators that much. It's very seldom the buyer that is the user”

to do with tradition also, the market is very conservative. Maybe the northern countries are less conservative? The most conservative is the one in the US. They prefer the machine that grandfather bought. It should look like that, not come with anything else that's what we are used to use. Please give us that! I have heard stories, when we are trying to sell silencers for example, they say "OK, you can send it with the machine but we are not paying for it!". No extra! And if we are selling it with them, okay don't fool us we know you can go down in price!” (20:10)

- Thomas: “In many cases the one who buys it just want the lowest price. They don't care about the operators that much. Olof: "It's very seldom the buyer that is the user. The typical customer in the US is a rental company [...] They don't care about the vibration. They don't care about the efficiency. If the performance is quite low, it can stay out another day. It's even better for them!”
FIELD STUDIES INTERVIEWS

customer in the US is a rental company. They rent out the machine for days and it come back. The only thing they want to do with the machine is clean it and send it out again. They don't care about the vibration. They don't care about the efficiency. If the performance is quite low, it can stay out another day. It's even better for them! (22:20)

“The advantage of a pneumatic machine compared to an electrical is that they are less complicated there are less parts in it. Easy to service — you don't have to be very skilled for it. Most of things could be done one the sidewalk. You could take it apart with simple tools”

• Olof: “The worst for them is if the machine breaks down. If it breaks down in the middle of a work task the operator is not very satisfied having to go back and get a new machine, so the durability is extremely important for many customers. They should also be easy to maintain in case it’s needed. They are sold because of their simpleness so to say. The advantage of a pneumatic machine compared to an electrical is that they are less complicated there are less parts in it. Easy to service — you don’t have to be very skilled for it. Most of things could be done one the sidewalk. You could take it apart with simple tools”, and the power is high also on that compared to electric” (23:20)

• What about hydraulic? Olof: "The hydraulic machines they are also powerful. They are comparable in power. I believe that a hydraulic breaker is a little bit more complicated and of course you need a powerpack and you need a compressor for a pneumatic breaker. The compressor might be a little big bigger and rough and tough and it’s also a lot bigger compared to a hydraulic powerpack. Thomas:’If you have a service car then a powerpack can be a very good solution, but I think the market is conservative, so that’s one challenge for the hydraulic breakers’. The market share, if we compare the hydraulic breakers to pneumatic breakers, they are an absolute minority. It hasn't been that big a success. Many are not aware that it exists, and it’s a little bit more complicated than the pneumatic machines. If you already have a compressor you don't need to calculate with that cost, with hydraulics you need to buy both a powerpack and a breaker and that is of course more for a hydraulic breaker taking into account that you already have a compressor. The compressor is of course also expensive, but if you look at concept versus concept” (24:30)

• Olof: "A more and more frequent solution is these skid steers on 4 wheels. (28:30)

— Video part 2

“Sometimes if you stand, pushing down, and suddenly it breaks! That can be a little bit annoying also. You put all your weight on it and suddenly it disappear, that could be awful for you almost”

“Earlier we had Milwaukee, Kangoo, and AEG that was electrical machines but they were sold in 2005 and or something. Olof: "And that time we realized that we were not competitive. I believe the competition was too hard for us. There are SO many good competitors in this segment”

“Thomas: “Historically from the 1960’s Atlas Copco invented machines that were both ergonomic in way of noise and vibration, so from that we have taken a huge step. It has been on the market for a long time”

• The machine volume in the way of the chisel? Olof: "To avoid getting the chisel stuck you want to put it in the right place and to do that you need to see of course” (2:45)

• "Sometimes if you stand, pushing down, and suddenly it breaks! That can be a little bit annoying also. You put all your weight on it and suddenly it disappear, that could be awful for you almost” (04:05)
FIELD STUDIES  INTERVIEWS

• Went away from electrical machines? Thomas: "Earlier we had Milwaukee, Kangoo, and AEG that was electrical machines but they were sold in 2005 and or something. Olof: "And that time we realized that we were not competitive. I believe the competition was too hard for us. There are SO many good competitors in this segment. I don't think we where really competitive at that time" (4:30)
• Batteries? Olof: "For small drills and things like that it became more popular. I don't know about the future of course, but nowadays we need quite a lot of power 1000-2000 watt or something like that, and with todays technology that would take quite a big battery pack to manage that. It's not impossible but today it has quite a lot of limitations as I see it. Thomas: "But on the smallest tools that's another question. We have 3 kilo small chipping hammers. (5:45)
• Looking into how much time you can use the different machines (comparison number chart)? Olof: "Then of course you should be aware of that many of our competitors, the sales figures they are very optimistic I would say. Often when test

"You should be aware of that many of our competitors, the sales figures they are very optimistic I would say. Often when test the figures we come to twice as big figures and things like that, so take it for what it is. Don't rely on it too much" (7:00)

• Are the impact energy for the pneumatic and hydraulic breakers secret? Olof: "Actually, we are very restrictive when it comes to giving these and the reason for it is that we don't want it to come out on the market. And the main reason is that we believe that some of our competitors can use it against us"

"We are very restrictive when it comes to giving these and the reason for it is that we don't want it to come out on the market. And the main reason is that we believe that some of our competitors can use it against us"

that we believe that some of our competitors can use it against us because then they can claim out some figures that we can't prove. And we are afraid that they will give much higher values which accordingly to us is not true but they will use it in their marketing and we won't like to go into that discussion. (7:50)
• Electric breakers claim to be higher? Olof: "the energy level you see on the Cobra that's the energy that goes into the chisel. Most of the competitors that's the power that goes into the cord, not what comes out. (Me: It says impact energy). It's not true. I would doubt if any of these goes above 60. I would say that this is the power that goes into the cord. Thomas: "Sometimes they are giving figures just for a single stroke. With this percussion mechanism you can have 1 stroke that is very powerful and then you have 5 less powerful and then you have 1 powerful again and they only give the figures for that 1 powerful stroke, but if you have the average then it's much lower. It's quite complicated to measure, it's hard to compare figures from different laboratories and things like that" (9:14)
— Sound file

• Thomas: "More in general you can say that electric and petrol machines are the most efficient. Pneumatic and hydraulic are the less efficient in terms of energy"
“Talking about the efficiency of the machine is one thing, but we really need breaking efficiency and that’s more about the design of the mechanism, how the piston and the working tool are matched, how the shape of the stress wave can break in concrete”

NAME THOMAS LILJE
COMPANY ATLAS COPCO / DEMOLITION TOOLS
OCCUPATION DESIGNER
BACKGROUND MECHANICAL ENGINEER
EXPERIENCE 10 YEARS

NAME PÅR ARONSSON
COMPANY ATLAS COPCO / DEMOLITION TOOLS
OCCUPATION LAB TECHNICIAN
EXPERIENCE 15 YEARS

— Interview video
• Cobra Pro. Kalmar design, with about 60 Joule in energy output. 25 kg.
• “If you look at how change the chisel you are using your foot. We call it the retainer. It’s a similar system on all 3 breakers” (0:45)
• Wacker Neuson EH 23, 25 kg.
• “This is pneumatic TEX 230 with ergonomic handles, spring loaded to reduce vibrations. They are produced both with stiff handles and ergonomic handles. This technique with the spring loaded handles give a reduction, from 15 m/s² to below 5 m/s². It’s a quite simple solution but it’s very effective at reducing vibrations (2:30)
• How heavy is it? ”28 kg with the handles. The handles are much heavier because they are solid in cast steel an the other ones are plastic with a hole in. I think it’s about 5 kg for the
handle and the springs more than the stiff one. That is one trick also you need to weight the handles to get the vibration reduction in a spring loaded system. (3:40)

- Backe has a spring loaded system (5:09).
- One thing in the design is, to work with the machine you want to see the chisel so it's more flat here and wider (TEX 230). If it's too bulky you have to stand like that (bend over). Like this type of machine (Cobra Pro), it's a little bit too bulky. You can't really see the [chisel]. (6:10)

“• What we can deal with is the feed force of the operator and the weight of the machine [...] so if we hall develop something there's 2 ways. One is to make the operator stronger. The other way is to change the weight of the machine”

bulky. You can't really see the [chisel]. (6:10)

- One major limitation is the feed force the operator can give the machine. Between 15-20 kg depending on the spring systems. I think you must feed this one a little bit more than the petrol breaker because you have that type of springs. What we can deal with is the feed force of the operator and the weight of the machine. So in this case we have 20 kg from the operator and 25 kg from the weight of the tool, we have a total feeding force of 450 Joule and that's the power you can put in the machine not to extend what the operator can feed it. So if we shall develop something there's 2 ways. One is to make the operator stronger. The other way is to change the weight of the machine. (7:00)

"Also you had some questions about efficiency, and that's roughly the output you have in the chisel divided with the energy input have into the machine, and if we compare, electric and petrol breakers are more efficient than pneumatic. You have a big input from the compressor to the pneumatic breaker. You have 1200 watt out and maybe 8000 in. They are, I don't know, old types of machines. Their durability is very good and you can throw them and so, they don't break. They are very robust and easy to service. Few parts. So this is more or less the old type of machine but it is still living because it's robust and easy to service and cheap to buy. You can have more or less 4 of these for 1 of the petrol breakers. You have much more parts in the Cobra and the technology is more expensive (9:10).

• “And electric machines. For indoor use they are the best solution. (Me: So you don't really produce much for indoor use?) No, it's more for outdoor use, the machines we have (19:50)

• Do you think you will go electrical again in the future? Thomas: "My personal view is that electrical machines will take more market shares'. Pär: 'I think so, but in our case, Atlas Copco's case, we don't have electric tools. It's a very big market to grow in. I think we need to have electrical versions of the breakers". Thomas: ‘And of course the competitors of

“Electric machines, for indoor use they are the best solution [...] it's more for outdoor use the machines we have”

the electrical breakers, they are very aggressive" (13:30)

• "What we really need is effective breaking. Talking about the efficiency of the machine is one thing, but we really need breaking efficiency and that's more about the design of the mechanism, how the piston and the working tool are matched, how the shape of the stress wave can break in concrete. The durability of the stress wave and so on. How much the machine is capable of cutting in the concrete. So it’s not only the efficiency when we measure the input and output. The real work is the breaking efficiency of the stress waves into the concrete. The shape of the piston will change the shape of the stress wave working on the concrete’ (19:50)

• In many cases electric machines have a very short piston. In many cases that’s bad for breaking. They can have high energy but the breaking efficiency is lower. It’s a very short time of the stress wave where you have maximum load, and if it’s a longer piston it’s a longer time that you have a lot of power in there. It’s the durability of the stress wave. If you have longer stress wave you have a longer durability that will effect the concrete so that the elastic part of the concrete is loaded so much that it will break” (17:40)

It’s not easy just to compare efficiency. Power in watt can look very nice, you have maybe 2 kW but then you work with a machine that maybe have 1,5 kW you see the 1,5 kW breaking
much better than the one having 2 kW. It’s the picture of the stress wave. How it’s matched (18:45)

— Test 01 / TEX 230
• "I think one of the reasons they are so popular is that they are rather easy to handle. They have a good result breaking" (4:45)
• Me: "You use power to hold it down. But it’s also very powerful (vicious)"
Pär: "When you use them a little longer time you get to know the machine so you use the springs to work more because in the beginning you get a lot of...”

“ It’s not so high here but if you have bigger concrete blocks and you have half a meter to the ground and this breaks it’s very... (Oh, it doesn’t even hit the ground!), no you have the whole machine in your hand and you must get up with it again. And often if you have been standing working quite a while it takes some minutes and then you are more or less relaxed and then suddenly it breaks. It’s a very bad feeling in your back”

Me: "I tensen up. I can already feel it a little. I don’t feel the vibrations. It’s very good in vibration reduction”
Pär: "If you had tested the stiff one you would feel the difference"
Me: "I tried a Hilti 905 the other day and there I felt the tingling"
Pär: "Yeah in your fingers and a bit up your arms when you have tested them for like 5 and so for some of the machines. The guys that work with them for 8 hours a day it’s not very good because they have a lot of destroyed hands fingers and they loose the feeling and so”
Me: "The worst thing is that it takes so much time before you realize it, it takes many years to develop”
Pär: "Yes and then it’s too late. You can’t repair it" (5:00)
— Test 02 / Wacker Neuson EH 23
• Thomas: “there was some session where you where breaking through. That’s good in your opinion I think because that is hurting the back, when you are pushing and suddenly it goes through. That can be a problem. It’s not so high here but if you have bigger concrete blocks and you have half a meter to the ground and this breaks it’s very... (Oh, it doesn’t even hit the ground!), No you have the whole machine in your hand and you must get up with it again. And often if you have been standing working quite a while it takes some minutes and then you are more or less relaxed and then suddenly it breaks. It’s a very bad feeling in your back. (0:00)
• Me: "It’s an amazing difference...!”
Pär: "Yes, it’s the same as a Porche 911 and a Skoda Felicia!” (4:00)
• Me: "Wow! That doesn’t feel very efficient and I feel the vibrations more”
— Test video 02 / Cobra Pro
• Me: "It's funny even though it's lighter than the pneumatic it feels much heavier to maneuver” (11:50)
• Thomas: "What's your impression when you compare the different type of machines?” (12:00)
• Me: "The pneumatic breaker seems very good, very efficient. Even though the TEX 230 is heavier it’s really compact and small so it’s easier to steer, easier to see. With the Tex 230 you have the handle on the top and if you hang something in the top it want to hang straight (down). The balance is better on the pneumatic because it's slim you don't have more weight on one of the sides, it's the same on both and the weight is quite low. If you see at the bottom, it's quite heavy. That gives it a good balance”

Cobra you have this volume. When you lift it the balance of the machine makes the chisel point underneath you so it’s very hard to reposition. To move it out. When you go with an angle the frame is in the way and you have to move out even further. And when I got the hang of trigger, the TEX 230 has a very smooth start, it’s very nice. Maybe I just need more practise but it’s a bit harder on this one”
Pär: "I think if you have practised more with it you learn the way to start it, because you must have the throttle control and the feed, so it takes some time. If you use them a lot you have it in you” (14:00)
• Pär: "On the TEX 230 you have the handle on the top and if you hang something in the top it want to hang straight [down] like that but on the Cobra you have the handle more like
in the middle or so”. Thomas: “The balance is better on the pneumatic”. Because it's slim you don't have more weight on one of the sides, it's the same on both. Thomas: “And I will also say that the weight is quite low. If you see at the bottom, it's quite heavy. That gives it a good balance” (14:20)

• Me: “The Cobra is quite top heavy!”
• Pär: “Yeah, it's top heavy because you have the engine in the top of the machine”. Thomas: “It's easier to handle if it's low heavy” (15:20)
• Ever thought about adjustable handles? Pär: “On the Cobra it's adjustable. You can put it higher. But in Asia they have another problem. They want it lower because they are rather short people. They have problem with the Cobra because it's long. It's the same chisel. If you put the pneumatic breaker

“On the Cobra the handle is adjustable. You can put it higher. But in Asia they have another problem. They want it lower because they are rather short people. They have problem with the Cobra because it's long”

the maximum height is something like here (3/4 of Cobra)” (15:30)
• What's the reason for the metal frame? Pär: “it's petrol tank, some protection frame, and you have some springs for the anti vibration system and so. I think this machine was introduced in '97 so it's 16 years old so I think we need a... It's time for a new one! We need a more modern design. But the customer have liked them.
“With a robot you loose the feeling. It's a machine and you have 2 joysticks in your hands so you can't feel the feed force”

• Olof: "Amazing figures here on the Markita 82 J, I don't believe it, or the Dewalt!". Pär: "No, because we have tested this Hilti 3000 (68 J) and it's a very good machine so it's not easy to believe". Olof: "The Dewalt seems calculated on power input or something" (0:30)

• There's no way we are going to work with a Hilti 3000! Pär: "Maybe they're good if you make some big work on the floor, if you need to brake a bit more concrete, for pipes or so, they need a bigger machine but I don't think it's that common that you change the pipes in the basement and so" (5:30)

• Thomas: "For indoor use it's only the electric" (9:10)

• Talking about Brokk and loosing precision. Pär: "You loose the feeling. It's a machine and you have 2 joysticks in your hands so you can't feel the feed force" (11:00)

• They say that the Brokk is comparable to a Hilti 1000. Olof: "That sounds very strange to me! The Brokk should be 3 times as good as the Hilti 1000 at least! [...] 4 or 5 times as much power as the Hilti. You must almost believe that something is wrong with that one. It's not installed correct."
Of course when it's in position it's much more efficient but you are not as rapid to move around. It could be that maybe?
John: "It's interesting feedback, but in my mind the Brokk should be way better than the Hilti!" (12:10)
• Pär: "The Brokk robot with bigger breakers I think it's a rather common to work in tunnels, roofs, and walls, but it's bigger — it's the bigger size of the machine. And of course the safety you can stand some where on quite a long distance so if something falls down you don't need to be under the

“The manoeuvrability is of course one task, if it's very sensitive work — saving a pipe and take the concrete away around it — it's not so easy with a robot”

work. Thomas: "I think they sent Brokk robots to Japan Fukushima, nuclear" (15:00)
• Olof talking about a counter balance concept with a structure going over the head with a string down to the breaker (19:30)
• Smaller robots would not have enough power. Olof: "That could be improved quite easily I guess, when it comes to the power. The manoeuvrability is of course one task, if it's very sensitive work — saving a pipe and take the concrete away around it — it's not so easy with a robot. And of course you can improve the steering system. Maybe you know when doctors make hard operations they have some glove more or less they put on and [do tiny movements with large hand gestures]. Me: "If you have those gloves maybe they could also give feedback?". Yes, like a joystick to an X-box or something" (22:30)
• Pär talking about remotely controlled robots for swimming pools with asbestos, keeping the user in safety (24:25)
— Video recording 02 Test 01 / TEX 230
• In wood there is some frame detector scanning for density that could be used for pipe scanning (1:30)
• Pär: "The technology for robot, I don't think it's so expensive, because you have the X-bot and Kinects. The technology is there, rather cheap" (2:35)
• What about just a belt with a strap? Olof: "It becomes something a little like [the concept we did], and the important thing is of course that it's not limiting you, preventing your work task and I think that is the key. As long as it's not preventing you from reaching something, moving yourself or anything like that of course it's good. This solution here (their concept) having something pulling close to your face of course it creates a force down and it's bending your back" (3:50)
• Pär: "I think it's important to get rid of the breaker, if you

“We the technology for robot, I don't think it's so expensive, because you have the X-bot and Kinects. The technology is there, rather cheap”

need to pick something up, you need to go to the toilet or do something quick. Olof: "Just throw it where you are digging, get a wrench, connect something, change tool, the chisel, shut off the compressor". Pär: "It cannot be difficult to put on the body. People would think it's too difficult to use it". Olof: "Yeah and when people put on something like this people will start to laugh. If it looks like a fighting robot, transformers or something like that, it might be easier. This of course becomes very expensive. For the military maybe it cost like a million and it's okay for them but maybe not in every day construction (5:10)
• Is that the future getting the tools out of the hands? Thomas: "The remote I think is very possible". Olof: "To be a superman in a construction site is good also. You don't need any help, you can carry heavy things. You don't just need to use it for breaking. I think they have tried that with industrial manufacturing guys, was it Toyota or something like that, where it's a robot you put on yourself for using screwdrivers —releasing your own muscles from the work with the aim to get you to start working more efficient faster without getting tired (7:30)
• Pär: "We don't make the carrier we make the breakers. Brokk made a carrier for hydraulic breakers and our bigger breakers are for excavators and so on. We don't make the whole system we only make. So maybe it's hard for us.... They put out tools on the machine"
• Robot more compact than today? Olof: "The line between exoskeleton and remote robot is maybe not that straight. It could be something in between?" (10:30)
“It is a good idea, because the breakers are rather heavy. When you carry them around for a whole day you get extremely tired”

NAME ALEX
AGE 21
OCCUPATION WORKER (ROBOTS)
EXPERIENCE 2,5 YEARS

NAME PETER
AGE 38
OCCUPATION WORKER
EXPERIENCE 3,5 YEARS

• Sometimes they get stuck even with the big robots and they need to twist it from side to side. Then they don’t want the wheel to touch the ground and therefore they like mockup-2, due to the movability. If mockup-3 get a suspension it will be alright, because then it doesn’t hinder the movementy so much.
• They like the 1-wheel better than the 2-wheel because it is easy to move around and also it makes a lighter construction.
• They want the turning function of mockup-3 on the mockup-2. “The problem is the more complicated stuff you have in the machine the more likely it is to break [...] If the dust gets in somewhere it’s gone”

“The problem is the more complicated stuff you have in the machine the more likely it is to break [...] If the dust gets in somewhere it’s gone” (11:15).
• “I think it’s good that the wheel goes back. It’s more free somehow” (13:00). If they want to work in a steep angle it’s easier on mockup-2 than mockup-3. On M3 it would be harder to get the right angle and also the wheel moving backwards supports the weight of the breaker. Otherwise you need a really long chisel on M3 to reach down to the ground.
• They want to use their own power to push down and they...

If the dust gets in somewhere it’s gone” (11:15).
don’t feel like they are using that if the chisel is feded. They believe that you will loose some power. “Because it’s good if it helps you up” (26:29).

- Today it’s moving more and more towards less dust. “People scream and shout”, so a dust solution is very good. You could just have a little nozzle spraying towards the chisel. Some places they have problems with the water but mostly the

“If you are getting some crap away from where you are using the breaker it’s easier. You see better and the machine works better when there is not a lot of other stuff in the way.”

Concrete sucks up the water if you only have a small amount of water. When they are working with a lot of electricity the can’t even have a drop of water. You don’t need that much water to get control if you can just do it from the beginning, concentrated. “A handheld jackhammer doesn’t make so much dust. If I hold an ordinary dust control close to it it’s almost no dust” (18:40). If you would have one in that distance (from volume to chisel) it will take 90 percent of the dust. “It would actually make it easier to use the machine, because if you are getting some crap away from where you are using it it’s easier. You see better and the machine works better when there is not a lot of other stuff in the way” (19:00)

- The vacuum suction would be a good idea but it’s hard to imagine when you haven’t seen it. I’m not a visionary so I can’t see it. Not often but sometimes we keep a vacuum cleaner next to it.

- “It’s rather important that you can’t have the wheel too small. This is a good size. You have a lot of crap on the ground and if the wheel gets smaller it will get stuck in it” (20:35).

- If it’s a problem to twist the wheel for the sideways movement an alternative could be to lock the wheel of M2 in a moved out position and use it to pivot around, moving the chisel to the side. Though they would rather have the sideways wheel than doing this motion.

- Support leg? No I don’t think that it’s nessesary. “in the beginning maybe people would use it, but then, at least just me, would be tired of it and then just lay it down on the ground”.

- Scan for pipes/Cables? Yes, so you have a display on the top or a lamp, just green and red light. Also it could show the electricity.

- You could have a handle in the front for carrying it, to get up in the car or through a window

- Depth control? Problem on tapered surfaces about where to measure. We mostly use the chisel to see. We know how long it is and we see, but we don’t go with any specifics.

- They want a smaller handle because sometimes it’s narrow

“In the beginning maybe people would use a prop stand, but then, at least just me, would be tired of it and then just lay it down on the ground”

where they work and also a handle sticking out is more likely to get damaged. “Sometimes you get stuck even with our machine and it’s much smaller”.

- D-handle? No, it’s easier just to stand straight. You could have a hole and then it’s a possibility to put a handle.

- Handle position in terms of the distance from the body? Often when they drill they lay the body over the machine to press with the body instead of the arms.

“That would be a perfect thing. Maybe sometimes the wheel is in the way, so it will be a good idea to be able to detach it”

- Handle in the middle? No.

- Detach the wheel? “Yeah, that would be a perfect thing. Maybe sometimes it’s in the way, so it will be a good idea to be able to detach it” (32:10).

- “I really think it’s a good idea. It will help you out a lot. Yeah

“I really think it’s a good idea. It will help you out a lot… Yeah, I like it! I’m impressed!”

I like it! I’m impressed! But don’t over do it, with the handle over here (in the middle of the top), it’s a bit too much. Just keep it simple. When we do the stuff we don’t care if there’s a handle. We have this other handle and we just move it around”. It’s often that people just toss it around. The more stuff you have on there more likely it is to break (another point of why you dont want the handle to stick too much out). The want it to go all the way around (in a zero shape)

- “It is a good idea, because they are rather heavy. When you carry them around for a whole day you get extremely tired”.

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“It's a strange market, because Sweden used to be a market where vibration and performance were high value items and now they are going for the worst solution available”

NAME JAN OHLSSON  
COMPANY ATLAS COPCO / CONSTRUCTION TOOLS  
OCCUPATION ECONOMY/MARKETING  
EXPERIENCE 30 YEARS

• “I would change my job as well if I used those tools to do that (Hilti 905 and Dewalt Breaker). It like to use a kids toy to do serious work, but that’s not an uncommon thing to do”

• Everyone uses a Hilti 1000? “Yeah, because it’s easy available from the rental companies”

• “The weight-performance-ratio for electric machines at 30 kg is just not good. They don't have the punch to do the job. You get a lot of vibration and not the job done”

MARKET
• Looking outside of Scandinavia. The market is a little bit different than many other countries.

• Hydraulic breaker types and applications:  
  3-7 kg (D-handle breakers)  
The smallest ones — surface structural work. Changing the surface over concrete, ornamental work, small renovations.  
  8-15 kg (D-handle breakers)  
Relatively simple and small to carry around and work with — both horizontally and vertically. Little heavier work a little harder materials, but still usually for renovation/rebuilding. Then usually they go into industrial applications like filmstripping.  
Target group (3-15): Rebuilding, renovation, repairs. Buy or rent the tools so rental companies is also a target group.  
  15-25 kg (vertical T-handle breakers)  
Service work, infrastructural servicing, repairs on concrete/hard materials. Target group: Gas-, electricity-, water and sewage companies. Also quite popular with rental. Some of the heavier ones for companies doing demolition jobs, and renovation rebuilding to a certain degree.

“There is too little knowledge in the young guys today, they never used these tools and they think that everything that's electric is simple so therefore it's good. The problem is it's simple but not good!”

• “It’s a strange market because Sweden used to be a market where vibration and performance were high value items and now they are going for the worst solution there is on the market”

• “If they would have used a pneumatic tool they would have gotten (just that) the performance and a lighter tool. The problem is nobody is caring about that in the market, because there is too little knowledge in the young guys today, they never used these tools and they think that everything that's electric is simple so therefore it's good. The problem is it's simple but not good!”

“The Scandinavian market isn't particularly interesting for several reasons and one is pretty good — the Scandinavian market has mechanised quite a lot. Mechanization is a good thing when it comes to heavy tasks, so there we are selling hydraulic attachments for small mini excavators or Brokks”
30-45 kg
Demolition.
Target group: Heavy road construction (countries outside of Europe), demolition specialist companies (demolition work where you cannot with any efficiency use robots). Last 20 years quite a lot of substitution Brokk robots and small excavators with hydraulic attachments on them. There you have a certain degree of mechanization.

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• 25 kg weight class is quite popular. It has a more all-round usage and of course if you look at a product like the 230 or 220 it's quite popular in many markets, but depends what kind of typical application you have in the market. If they have much demolition they would use heavier breakers if they have a lot of repair work they might go for smaller ones as well. In the hammer sizes I would say that the 9 and 12 sizes, between 10, 12, 15 kg, for vertical and horizontal work, they are the most popular. But also the small 5 kg unit is quite popular.

• Biggest markets? "North America. Certain countries in Europe. The Middle East. That's the bulk of the tools but they are everywhere — bigger and smaller amounts. If you look at pure numbers the big numbers are in China, but those tools look totally different and they don't have the same life cycle or anything like that so, it's not really comparable. You take 6 of their tools and it won't last longer than one of ours.

• The Scandinavian market isn't particularly interesting for several reasons and one is pretty good — the Scandinavian market has mechanised quite a lot. Mechanization is a good thing when it comes to heavy tasks, so there we are selling hydraulic attachments for small mini excavators or Brokks. If you see a Brokk there would be an Atlas Copco hammer on it. We have no reason to substitute a handheld product for that one, because that would be like going a number of years backwards in a country where there's economic possibilities to do that. And in our countries the buildings are much concrete. In other countries it's not concrete so much and of course you don't need as much power as you get from a robot like this. In general we are a little bit smaller in Scandinavia than we should have been, on the other hand it's not really a focus market.

• Compact robots in smaller spaces? "What we have developed the last 4-5 years are vibro-reduced tools, that are lighter than used to be the case 20 years ago, and with the good performance of a pneumatic tool instead of the not so good performance of an electric tool. So we have targeted the markets that are conscious about vibrations, which is an increasing number of markets, including Scandinavia of course, with a group of tools which is much better than what have been in the market earlier".

“The only problem is that in Scandinavia to get acceptance of these tools, because people are not used to look for these tools anywhere else than the electric tools market”

"If you look at Sweden, Norway, you will see that people are SO into electrical tools that they don't see any alternative. They don't look for any alternative because that's what they think is there — and it's a big task trying to turn that".

LIGHTER THAN USED TO BE THE CASE 20 YEARS AGO, AND WITH THE GOOD PERFORMANCE OF A PNEUMATIC TOOL INSTEAD OF THE NOT SO GOOD PERFORMANCE OF AN ELECTRIC TOOL. SO WE HAVE TARGETED THE MARKETS THAT ARE CONSCIOUS ABOUT VIBRATIONS, WHICH IS AN INCREASING NUMBER OF MARKETS, INCLUDING SCANDINAVIA OF COURSE, WITH A GROUP OF TOOLS WHICH IS MUCH BETTER THAN WHAT HAVE BEEN IN THE MARKET EARLIER".

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Portability issues with compressors or powerpacks? “In many work sites there is already a compressor that you can use and the portability is not that bad, because you can have light weight hoses. It’s what people are used to. If you look at Sweden, Norway, you will see that people are SO into electrical tools that they don’t see any alternative. They don’t look for any alternative because that’s what they think is there — and it’s a big task trying to turn that. But slowly the more professional ones having tougher tasks they’re starting to look for other things because productivity is so much better and we actually have a better vibration level.

It’s a matter of mind-set. In Denmark pneumatics have been available and have been a recognized power source up till today. It’s not uncommon in a work site, but in Sweden for some reason people turned away from pneumatics when the electric tools came. In a way it was considered to be old fashioned, but it also very effective/efficient and I think they are missing out on something there.”

“Breaking as big pieces as possible, that’s the efficient way!”

• Price of electric breaker vs. pneumatic + compressor. The average life cycle of an electric breaker is not very long. It’s a tool you always risk to burn out if you overload it and if you have a tough job for it you will wear it — so they will need servicing. You won’t expect 10-12 years coming out of a tool like that. So the buying price you can’t set up against a set of pneumatic tools and a small compressor. The tool will last 7-10 and the compressor longer than that, so you have to take more or less the cost of ownership into consideration when you look at these things — life time costs and the cost per year, because if you just look at the price tag you are going to end up with the wrong conclusion.

• Workers don’t care about life cycle since they rent? "That’s correct but of course you also have to look at the performance. If you have an 8 hour work shift and you have a rather high vibration level on the tool you will come into violation with the vibration exposure rules that you have in Europe today. And with a tool that have too little power you can’t have a tough job for it you will wear it”
will have a lot of vibration normally, because if it's trying to do a job it's too small to do the result is more vibration to the operator. If you look at a tool that's bigger of course it will do the job quicker (will it?) and with less vibration. Maybe you

“Of course you can't mechanise small tasks, renovation, rebuilding, more than to a very limited extend. There is a limit where it's not feasible, practically or economical to do that”

don't even have to work a full 8 hour shift.

- "The rental companies don't care about that (efficiency), because they are interested in renting the tools out as many hours/days as possible, so then it's not a problem with productivity really. What ever the operator ask for he will get and if it happens to be a tool that will take 3 days to do what could be done in one day they will be happy about it, I think"

- "No new user groups are being added. More and more market groups are being added, because 10 years ago you would still see people doing this by hand with a sledge hammer. In India and Africa you still see people doing these jobs with other tools. What happening is that you have a

“We are working both sides of this market — the Brokks robots and tools for lighter jobs that still need to be handheld”

spread of this type of technology into new markets, where it's replacing older methods. The total market is still growing in the world, but it's growing mainly outside the industrialized countries. The industrialized countries market is rather stable.

- Is the market going towards the work being handled by robots? "If you look at the heavy applications, yes. If you look at big demolition sites you will use hydraulic attachments one way or the other — a hammer, crusher, pulverizer or something — to cut down buildings, because you get so much more efficient and also it's very friendly for the operator and for the environment to use these type of tools,

“That's what makes his work easier. Then he is not so much a positioning device as more a user, because if you turn the operator into a positioning device then he is having a tough time”

but of course you can't mechanise small tasks, renovation, rebuilding, more than to a very limited extend. There is a limit where it's not feasible, practically or economical to do that, and there is of course a market that's still there. We are working both sides of this market — the Brokks robots and tools for lighter jobs that still need to be handheld"

- Robots in the future with same portability as the breakers?
"Haha, quite frankly I have seen number of tries and they have been miserable all of them! I have seen a number of suppliers trying to mechanise contractions, where they have tried to put in a handheld tool fixated to something that is used as a pedestal for the tool to do the work and I have not seen a single one that has been workable in a real environment. "It must be very easy to handle to make it work" (Thomas). I use the saying if you have an 8 kilo hammer and you need 60 kilos of machinery to handle it you are probably not on the right track, because the work sites never look like that. You can't do that. I think we have chosen another route which is to bring down the weight and to bring down the vibration exposure as much as possible for the operator because that's what makes his work easier. Then he is not so much a positioning device as more a user, because if you turn the operator into a positioning device then he is having a tough time"

- Market for more specialized tools — more compact solution that can only work on floors? "You should never say never. There have been a number of trials to make cheaper, smaller and simpler tools for this, and so far a lot of good people have tried but none of them have succeeded, but some day maybe somebody comes up with something that works. I'm not so optimistic, I think it's better to make it easier for the operator to use what's available in the market and that works. But then again if you do something that is very little and can do the job, well fine I would be more than happy to see that”
Angle/Stuck/Break-size

- "If you just hit straight down nothing happens. The chisels are often angled down, because then you get a better break in the concrete" — "if you just break down maybe you will get stuck" — "It's heavier to use" [when breaking on an angle] because it doesn't stand on it's own, you have to hold it" (4:20) [Markus]

- "The trolleys are too clumsy, because you have to move a lot, you hit it in different angles, you break, and the machine is often moving all over the place [...] if you have it on wheels it's not so effective. If you are going to hit one point. It's okay but the reality is not like that" [Markus]

- "Especially when there are water pipes, they need to go from different angles... They need to change angle. The thing that is hard about the Brokk robots is to do precision work, to control the drill like when you are actually holding it in your hand, which is one of the reasons they are still using the hand machines — and because they don't need to take a big machine with them! (28:30) [Johan]

- "The bigger pieces the better because then you get the work quicker done" [Markus]

- Sometimes if you take too big bites the chisel get stuck and then it's quite annoying and it takes a lot of force for you

- A rule of thumb is that you shouldn't take larger pieces than you can break with the machine in 10 seconds. [Thomas]

To avoid getting the chisel stuck you want to put it in the right place and to do that you need to see of course. [Olof]

- If you use a tool that will break away the piece of concrete in less than 10 seconds, your tool is too big — you will lift a lot of times but you wont achieve much. With the pneumatic you might not get these small pieces but it's not that common that it's a requirement. [Jan]

- Breaking as big pieces as possible, that's the efficient way! [Jan]

Weight vs. Efficiency

- "You have to put a lot more pressure with the Hilti. You have to push it down to get the floor in pieces. You have to put some weight on it. The Dewalt is so heavy in itself so you don't have to place some weight on it. It works by itself, but then I break your back when you have to lift it up" (2:45) [Niklas]

- A normal operator can give 200 Newton or 20 kilos in feeding force, the rest we get from the weight in the machine [Olof]

- If we liked to we could take away wide weight. We could make of plastic and make the wall thicknesses thinner etc., but then we would need to reduce the power because otherwise we need to push the machine much harder downwards. That is a problem. I would say that is the main limitation for how much power we can put in the machine. [Olof/Thomas]

- That is one way of changing the weight of the machine having it heavy when you need it and light when you are lifting [Olof]

- What we can deal with is the feed force of the operator and the weight of the machine [...] So if we shall develop something there's 2 ways. One is to make the operator stronger. The other way is to change the weight of the machine. [Olof]
**Breaking Efficiency**

- What we really need is effective breaking. Talking about the efficiency of the machine is one thing, but we really need breaking efficiency and that's more about the design of the mechanism, how the piston and the working tool are matched, how the shape of the stress wave can break in concrete. [Thomas]

- So it's not only the efficiency when we measure the input and output. The real work is the breaking efficiency of the stress waves into the concrete. The shape of the piston will change the shape of the stress wave working on the concrete. [Thomas]

- In many cases electric machines have a very short piston. In many cases that's bad for breaking. They can have high energy but the breaking efficiency is lower. It's a very short time of the stress wave where you have maximum load, and if it's a longer piston it's a longer time that you have a lot of power in there. It's the durability of the stress wave. If you have longer stress wave you have a longer durability that will effect the concrete so that the elastic part of the concrete is loaded so much that it will break” [Pär]

- It's not easy just to compare efficiency. Power in watt can look very nice, you have maybe 2 kW but then you work with a machine that maybe have 1.5 kW you see the 1.5 kW breaking much better than the one having 2 kW. It's the picture of the stress wave. How it's matched [Pär]

**Height Adjustment**

- On the Cobra it's adjustable. You can put it higher. But in Asia they have another problem. They want it lower because they are rather short people. They have problem with the Cobra because it's long. It's the same chisel. If you put the pneumatic breaker the maximum height is something like here (3/4 of Cobra). [Pär]

- What about the length of the machine? If it's long you need to lift it very high

**Pipes/Cables**

- Sometimes cables/electric cords get damaged. "The biggest problem is when you hit a water pipe in the floor. Often when you're going to take away — first there is the concrete floor, then there is the "kage (cookie)" and often they put the pipes in it — then you start breaking and then it gets wet [...] Maybe its like 10 times a year when you don't know what you are going to hit” (23:00) [Markus]
Exposure Limit Rules

- “We don't just work 15 minutes an hour, then it would take a hole year to get the job done” Peter
- “You can work with it 15 min each hour and then you need a 45 min break, but that never happens [...] You work with it to the job is done!” (9:50) Peter
- He was using it all day (maybe 4-5 hours). Sometimes he was working with it for 2 hours before taking a real break. Sometimes he will take like 3-4 minutes. (Peter)
- “Nobody cares about this 45 minutes, you use the machine until the work is done — but it's always a free choice” Markus
- It's never so much time they use the Hilti's. Mostly bumps [Markus]
- You can use the breakers in “different kind of steps. First you can use it for about 45 min a day. If you have been to the doctor and get an examination then you can use it for 120 min or something and then you have to stop. You can never use it longer. But when they are 2 people they change often so you don’t get tired and you wont get any problems with your arms or hands” (15:44) [Markus]
- Peter working 4 hours on a day? “Yeah it's often like that. It's about getting the work done, nobody cares about this 45 minutes, you use the machine until the work is done — but it's always a free choice. There is regulations... Kind of regulations... How long, but [...] many that works with these machines know these time limits, but it's more about doing the work. But then they [only] use the machine maybe one time in 2 weeks. It would be different if you use it every day then this time limit would be very important to follow” (16:30) [Markus]
- He doesn't use the 1000 that often, since he is mostly driving robots, but around 1-2 times a week for like 2-3 hours [Alex]
- Do you feel it in the body after using it? “No... No, you can't use it all the time without stopping because you stop for a moment to look at the result for what you have done, and then your body and hands get to rest and then you go again, so it's maybe only like 5-6 times I have really felt it when I came home since I started 2,5 years ago. That's mostly because I have a hand injury, I cut off some nerves” [Alex]
- 2 guys used 1,5 weeks to carve out the floor in a big room. They were working all day every day. They where looking at a Brokk, but the price difference was pretty big and they found it too expensive (2:30) [Johan]
- What can happen to the body? “I'm not an expert but back problems arms sore, that kind of stuff. The most guys are professionals. They use them every day like 3 times in a week. We never hear any complaints. Never. Well sure, the private guys who have never used them before they would say "ah, my back is hurting", I don’t think they are used to it. They just search on the internet how to do it and they come here, but they don't really know what to do with it. The big companies that rents them they have a pretty hard schedule to follow. They put the standards by themselves — you can only use this for 15 minutes. We also send notes with the tools going out on daily basis, we write "effective work time expected 15 min" [Johan]
- “There's a lot of machines and they all have the same problem, you can only use it for a limited amount of time” (14:00) [Johan]
- How long can you work with the Hilti? “I have no clue” [Fredrik]
- How long do you work with it? “All day, but usually we are 2 so we can shift. Normally we get 1 or 2 day jobs. Small jobs. We only work with water damage, which is usually at a regular persons home” [Fredrik]
- “The work always takes more time than they want it to be” [Fredrik]
- It's a busy period now for us when the ice/snow starts melting it's going through the ceiling. That's on top of all the normal water damages that come. Last month I did 219 hours!” [Fredrik]
- Many places they work from 9-16, Monday to Friday, but they don't want us to make any noise so we can only do it in the evenings and on the weekends. Then we work 7-16 and then go there afterwards. [Fredrik]
- “We are not allowed by regulation to use this Hilti more than 2,8 hours a day per person. I don't know how much it is for the big one but lets say it’s 2 hours there. You CAN work that efficient for 2 hours but not a whole day. If you go by the rules and have many people to pass it between, then I think it can be very efficient. If we are working longer than 0,8 hours with the Hilti a day, the
company has to find other ways for us to do the job. We should use those machines as little as possible (7:15)

- When you ask the operators how much they have worked they say a full day, 8 hours, and when you look at the clock seldom more than 2 hours, because they are doing so much more — breaking, changing position, taking away concrete, having a break, bringing something, getting something. So even if they believe that they have worked with the machine 8 hours they have very seldom done that. [Olof]

- In most cases these tools are made for service works, cutting small holes. You are not tearing down a whole building with them. It's quite limited work. [Olof]

- If you have an 8 hour work shift and you have a rather high vibration level on the tool you will come into violation with the vibration exposure rules that you have in Europe today. And with a tool that have too little power you will have a lot of vibration normally, because if it's trying to do a job it's too small to do the result is more vibration to the operator [Jan]

**SUMMON UP ERGONOMICS**

**Vibrations**

- "I have tried so older machines, the 905, and the difference is significant! Amazing actually! When you use the 905 it's like it slaps back in you hand more than the floor, but in these new machines you barely feel anything’ [Alex]

- "Then you have the small machines with small vibrations and they are actually the ones who are more dangerous, because you don't think of it that much [...] but actually we are not using them that much, just for small, small stuff” [Alex]

- Use gloves to take away some of the vibrations [OCAB]

- "You can work you back but you can't do anything about the vibrations. You can wear gloves but you can't do anything more, but you can work your back so it becomes strong before it breaks” (1:00) [Fredrik]

- Vibration feel? "It feels like when you leg is falling asleep. It's not good. The heavy kinds of vibrations doesn't feel as bad like with the multi cutter, a saw with 14000 RPM, if you do that one. And it's hard to use vibration gloves on that one because it's like having heat-gloves on. You have to be so sensitive“ (4:30) [Fredrik]

- During the past 10 years we have worked quite a lot with vibration, trying to minimize that as much as possible [Olof]

- Quite surprisingly many prefer the non-antivibration and the reason is of course the cost for it, it's cheaper and less complicated and it's more likely that it will last longer before maintenance. There is less parts that can break [Olof]

- When it comes to vibration you are allowed to sell any machine with any vibration levels. The only thing is that you can't use it for a long time [Olof]

- It's up to the employer when he employ someone he must make sure that each and every employee is not getting vibration dose higher than a certain amount. So in case he has a machine that vibrates a lot, he can use it but only for a very short time, and if he have a machine with lower vibration he can work longer time. Maybe even up to 8 hours. [Olof]

- One of our worst machines you might even only be allowed to use half an hour or something like that and then it's up to the employee and the workers to share the work. Lets say you have 5 workers working just half an hour each and the rest of the day they need to do something else. So there is no certain limit it's just allowed working time. That's of course a sales argument from our side when we can give them machines with low vibrations, but surprisingly not many is caring about this. [Olof]

- Historically from the 1960s Atlas Copco invented machines that were both ergonomic in way of noise and vibration, so from that we have taken a huge step. It has been on the market for a long time. [Thomas]

- You should be aware of that many of our competitors, the sales figures they are very optimistic I would say. Often when test the figures we come to twice as big figures and things like that, so take it for what it is. Don’t
Vibrations (Continued)

- rely on it too much. [Olof]

- We are very restrictive when it comes to giving these and the reason for it is that we don't want it to come out on the market. And the main reason is that we believe that some of our competitors can use it against us because then they can claim out some figures that we can't prove. And we are afraid that they will give much higher values which accordingly to us is not true but they will use it in their marketing and we won't like to go into that discussion. [Olof]

- Sometimes they are giving figures just for a single stroke. With this percussion mechanism you can have 1 stroke that is very powerful and then you have 5 less powerful and then you have 1 powerful again and they only give the figures for that 1 powerful stroke, but if you have the average then it’s much lower. It’s quite complicated to measure, it’s hard to compare figures from different laboratories and things like that. [Olof]

- Yeah (you feel the tingling) in your fingers and a bit up your arms when you have tested them for like 5 and for some of the machines. The guys that work with them for 8 hours a day it’s not very good because they have a lot of destroyed hands fingers and they loose the feeling and so. [Pär]

Dust

- Dust a problem. "Yeah you should use a mask". If you are in an apartment you use air-cleaners. They put plastic on the doors and it sucks out the dust. "If you are in a sensitive place, also in construction sites then we use air-cleaners". [Markus]

- With the robots they often use water-mist to take down the dust. It doesn't create problems because it doesn't matter if the bare floors get a little bit wet. The concrete sucks up the water too. [Markus]

- "You can use dust machines on the breakers, but it's not used so much because then you have to have a vacuum cleaner connected and you have to have the hose" — “it has never been used before and that's the reason” (20:00). [Markus]

- How long time does it take to set up the dust suction? "30 min maybe [...] It's not so complicated" (21:00) [Markus]

- What if the breakers was sucking in the dust? "Could be good but you always have to connect something to it, otherwise the machine gets too heavy. You can't have like a holder on the machine" (21:30) [Markus]

- Many people rent air-cleaners [Kenneth]

- The micro filter in the vacuum cleaner lets out 99.97% clean air into the room. It will keep the worker safe from asbestos, silica etc. [Kenneth]

- Is hose in the way? "The most times you are on one spot like in the bathroom working on the drain"

- In Sweden we call it Atenit, because it can last forever. It's not hazardous as long as it lays there. When you work on it cut in it like you do with the machines the fibres get out, and if you breathe them in they can cause lung cancer. [Fredrik]

- It's a good thing we wear this masks. Otherwise all this shit would be in my lungs. Some of those we work with don't use these masks. They say they don't like it. (2:45)

- Dust is something that we haven't worked a lot with but we believe that it will be one of the future challenges for us. We believe that will be more and more important [Olof]

- From what we have seen so far many of these (dust solutions) are not very efficient and they prevent the operator to do his work. Maybe they are blocking the view of the chisel so he can't see where he's working. Also they become very big and clumsy [Olof]

- On breakers it's not so common to use dust collectors. We haven't really seen any good solutions to this but we believe that we have to look into this. [Olof/Thomas]

- When they are using rig mounted attachments they have water sprinkle system attached to the machine body and they spray the area with water and also behind and beside the machine, binding the dust to the ground so to say. I think it can be a good solution. [Olof/Thomas]
Crowbar Movement

- Recognize crowbar movement? "Yes of course, you always try to break as big pieces as possible" [...] "The bigger pieces the better, because then you get the work quicker done" that’s why they use it as a crowbar. [Markus]
- "When working with floors you often try to go under the floor and break it up, then you use your shoulders a lot" [Markus]

"Drop"

- Sometimes if you stand, pushing down, and suddenly it breaks! That can be a little bit annoying also. You put all your weight on it and suddenly it disappear, that could be awful for you almost [Olof]
- If you have bigger concrete blocks and you have half a meter to the ground and this breaks it’s very... (Oh, it doesn't even hit the ground?), no you have the whole machine in your hand and you must get up with it again. And often if you have been standing working quite a while it takes some minutes and then you are more or less relaxed and then suddenly it breaks. It’s a very bad feeling in your back [Thomas]

Feeling Body

- "I still feel it in the shoulders from yesterday... That I worked out a little bit" (Peter)
- Can you feel the work in the body sometimes? "Oh yeah, it’s paid training" (Peter)
- "You get tired! You don’t get the strength to work so long" (3:30) [Markus]
- Do you consider the breakers the hardest tool to use? "Yeah I think so, because that tool affects your body most, and it affects your hands — many have problems, they get white hands" (13:22) [Markus]
- "Is the days always as tough? "No, but some days it can be tougher, like when you have to carry out the pieces in bags" (5:30) [Fredrik]
- Yeah of course if you are working a long time it will hurt your back [Thomas]

Future Perspective

- Body wears out before time? "Your body is working harder for the work we have instead of sitting on a chair, typing on a computer, but if you do this work right, you get a lot of training, which is good" (35:30). [Markus]
- "I don’t think that people that rents the 1000’s reflects much on what it can do to themselves. There’s a lot of young guys coming in 18-20, they just pick out the machine because that’s how you do it, they just do the work" [Johan]
- Any changes over the years? "I think that they have put the most energy in how to make the machines more effective and not so much the weight or something else. To make them pound harder" (18:00). And to be more gentle to the body? "No I don’t think so! The 3000 is a little bit different, you got the handle that comes along — it’s not stiff like the 1000, so I guess they are actually coming a bit on the way" (18:20) [Johan]
- Will tools change in the future? "People put higher standards all the time, making it more ergonomic. The companies want it to be more ergonomic so it has to be more ergonomic. They don’t want their guys to retire 5 years early, so of course they want their workers to be healthy" (19:30) [Johan]
- Would people be willing to pay extra for enhanced ergonomics? "Yeah, definitely. I would say the big companies that puts the standards. If they come in here and they have to pick between a Hilti and another machine that does pretty much the same work, it’s easier but costs more, they would definitely pick the one that costs more. They want their guys to be well"
- Would the company pay more for a better tool? "Yeah, I think so. I think they want us to be healthy as long as possible" [Fredrik]
- You think about how you use your body? "Yeah I do that (Niklas). I don’t think about it so much, but you use the mask if you feel like you need it, you try to use the gloves as much as possible” (19:00) [Fredrik]
- "I don’t think you can work in this job until you are 65. You will break your body before that” (19:00) [Fredrik]
- (The worst thing is that it takes so much time before you realize it, it takes many years to develop) Yes, and then it’s too late. You can’t repair it. [Pär]
Pneumatic Breakers

- Why don’t you use hydraulic/pneumatic breakers? “If you use hydraulic [breakers] then you need a power pack and it’s too clumsy and too heavy to bring around [...] you need the hose for the oil to circulate, it’s a little bit clumsy to have that and also it’s more heavy” [Markus]

- Many of these pneumatic breakers they are quite heavy, and they are heavy for one reason, that is when the power is high you need to push it downwards to work in a good way. To avoid having too much feed force from the operator we load the machine with weight. [Olof]

- If we liked to we could take away wide weight. We could make of plastic and make the wall thicknesses thinner etc., but then we would need to reduce the power because otherwise we need to push the machine much harder downwards. That is a problem. I would say that is the main limitation for how much power we can put in the machine. [Olof/Thomas]

- They are sold because of their simpleness so to say. The advantage of a pneumatic machine compared to an electrical is that they are less complicated there are less parts in it. Easy to service — you don’t have to be very skilled for it. Most of things could be done one the sidewalk. You could take it apart with simple tools, and the power is high also on that compared to electric. [Olof]

- They are, I don’t know, old types of machines. Their durability is very good and you can throw them and so, they don’t break. They are very robust and easy to service. Few parts. So this is more or less the old type of machine but it is still living because it’s robust and easy to service and cheap to buy. You can have more or less 4 of these for 1 of the petrol breakers. You have much more parts in the Cobra and the technology is more expensive [Pär]

- If you want a hydraulic or pneumatic you need another power source. It’s a cost thing but it also makes a much more efficient work and much less vibration [Jan]

- In many work sites there is already a compressor that you can use and the portability is not that bad, because you can have light weight hoses. It’s what people are used to. [Jan]

Hydraulic Breakers

- The hydraulic machines they are also powerful. They are comparable in power. I believe that a hydraulic breaker is a little bit more complicated and of course you need a powerpack and you need a compressor for a pneumatic breaker. The compressor might be a little bigger and rough and tough and it’s also a lot bigger compared to a hydraulic powerpack. [Olof]

- If you have a service car then a powerpack can be a very good solution, but I think the market is conservative, so that’s one challenge for the hydraulic breakers [Thomas]

- The market share, if we compare the hydraulic breakers to pneumatic breakers, they are an absolute minority. It hasn’t been that big a success. Many are not aware that it exists. [Olof]

- If you already have a compressor you don’t need to calculate with that cost, with hydraulics you need to buy both a powerpack and a breaker and that is of course more for a hydraulic breaker taking into account that you already have a compressor. The compressor is of course also expensive, but if you look at concept versus concept. [Olof]

- A more and more frequent solution is these skid steers on 4 wheels. It’s more frequent that people are having equipment like this, and then they buy another hydraulic breaker and use the hydraulic system for this instead of the powerpack if they are just using it occasionally it’s just a few hours now and then it’s a solution that many prefer because these types of machines are becoming quite available and common. [Olof]
Hilti 3000

- "The Hilti 3000 is very good on the floor, but it's pretty heavy [...] It's a good machine for the right jobs (not walls)" (3:20) [Markus]
- "The 3000 is too big to do anything above the waist, it's only for the ground" [Alex]
- They only have had 2 rents on the 3000. Why? "People don't know that it even exists — bad marketing! On the other side there isn't much work you need a 3000 for." (09:30) But it's better for floors no? "Yeah, but it's big! I think that's the main problem. Just looking at it, people give up. They won't even get it in the car. We had it here for 2 weeks in the shop, showing it off, people were just laughing at it — there's no way we are taking that thing!" (9:40) [Johan]
  - Maybe they're good if you make some big work on the floor, if you need to brake a bit more concrete, for pipes or so, they need a bigger machine but I don't think it's that common that you change the pipes in the basement and so. [Olof]
  - The weight-performance-ratio for electric machines at 30 kg is just not good. They don't have the punch to do the job. You get a lot of vibration and not the job done' [Jan]

Hilti 1000/905

- "It's difficult to work with it (TE 1000) over your head, sometimes you have to do that because the smaller ones are not powerful enough" [Alex]
  - "I have tried so older machines, the 905, and the difference is significant! Amazing actually! When you use the 905 it's like it slaps back in your hand more than the floor, but in these new machines you barely feel anything" [Alex]
  - You like working with the Hilti 1000? "I hate it! Maybe for 1 hour, because it's good to get the exercise, but I'm more of a robot kind of guy" (4:45) [Alex]
  - "Hilti are the best at making low vibration tools. They are very good! You can use the TE-1000 longer than any of the similar tools from the other brands" [Kenneth]
  - What are the TE-1000 used for? "It's a pretty broad spread. I would say bathroom floors. That's the most seen. (2:00) [Johan]
  - The most popular brand is the Hilti? "The one that runs the most through the door here is the 1000. The people coming in here they don't even say Hilti they just say 1000" (6:40) [Johan]
  - Other competitors that makes some good tools? "Yeah, Bosch... And Makita does some good stuff too. We got this deal with Hilti, they rent to pretty much all of Sweden, so we use it, and it works great for us" (7:00) [Johan]
  - "They pretty much take the 1000 even though they have a small plumbing because it runs faster, instead of standing there longer with a 300, or the 7 or 6. It's mostly floor work, if they work in shoulder height they go down to like a 300 or 500" (7:34) [Johan]
  - "We don't use the big breakers because it's easier to use a Hilti, because we are going to break the floor into small pieces and a van with a vacuum cleaner will come and suck up the pieces" [Fredrik]
  - The Hilti? "It's good. It's not too heavy and it does the most of the work it self" (2:15) [Fredrik]
  - "You have to put a lot more pressure with the Hilti. You have to push it down to get the floor in pieces. You have to put some weight on it. The Dewalt is so heavy in itself so you don't have to place some weight on it. It works by itself, but then I break your back when you have to lift it up" (2:45) [Niklas]
  - "I have only used Hilti for this type of job, but I think it is the best in comparison to other brands because they tend to be a lot more expensive. It's a big brand" (9:10) [Fredrik]
Electric Breakers

- Earlier we had Milwaukee, Kangoo, and AEG that was electrical machines but they were sold in 2005 and or something. And that time we realized that we were not competitive. I believe the competition was too hard for us. There are SO many good competitors in this segment. I don't think we were really competitive at that time. [Olof/Thomas]
- More in general you can say that electric and petrol machines are the most efficient. Pneumatic and hydraulic are the less efficient in terms of energy [Thomas]
- If we compare, electric and petrol breakers are more efficient than pneumatic. You have a big input from the compressor to the pneumatic breaker. You have 1200 watt out and maybe 8000 in. [Thoma]
- And electric machines. For indoor use they are the best solution [...] it's more for outdoor use, the machines we have. [Pär]
- My personal view is that electrical machines will take more market shares [Thomas]
- We don't have electric tools. It's a very big market to grow in. I think we need to have electrical versions of the breakers [Pär]
- And of course the competitors of the electrical breakers, they are very aggressive [Thomas]
- Of course you have an outlet in every work site, so it's simple to plug in and start running. [Jan]

Dewalt

- "I think it's too heavy. It's efficient but it's too heavy. You will break your back if you work with it all day" (0:30) [Fredrik]
- "I think the heavy machine will be hard to use if you have pipes in the concrete, because you have to be very sensitive to know where the pipe is and that machine is not so sensitive [...] I think I will break the pipe if I hit it, as hard as it hits" (1:40) [Fredrik]
- "You have to be iron man to have that machine" (7:00) [Fredrik]

Brokk Robot

- Is it the Brokk 40 too heavy for the scaffold? "No, but it's complicated... To get it up" [Peter]
- They have a Brokk 40? "We use that a lot instead of the Hilti 1000, because it's small, you get in with it. It's like with the trolley you can't bend the chisel on the robot, but it's stronger and you can use it for a whole day without getting tired, so it's a good tool. But it's pretty weak the 40]... it's not so much [power] to break with. Compared to the Hilti 1000 the power of the Brokk 40 is pretty much the same, it's just the time you can use it that is different. A man don't have the power to stand with a breaker all day" (24:30) [Markus]
- Is it more effective to use a hand tool? "It depends on what you are going to break. If you are going to break a "concrete cookie", if it's a big floor, the Brokk's are very good because then you can use it a lot. But if it's small stuff like in the shower where we break around the wells [...] the Brokk is not that good because you have to be more precise (25:30). Robots are good in big areas and hand tools in more tight spaces. [Markus]
- They have never used a Brokk in an apartment, then they use the TE-1000. The Brokk takes up too much space in a bathroom and "you have to be pretty steady on your hands so you don't break the toilet or the stuff in there. You can get some marks from the tires too", (29:45) [Markus]
- "Here we have 2 robots all day, all the time, sometimes we use handheld tools over the day, but I think I can count on one hand the days where we haven't used the robot" [Alex]
SUMMON UP SPECIFIC MACHINES

- The robots are very versatile. Beside breaking they can lift, dig, saw. "The versatility is important, but if you have a lot of money [a more specialized machine] is great because you save a lot of time" (15:30)
- "The downside [of the Brokk 330] is that it's very slow, runs on electricity and you have to move it with a truck. You can't move it on a simple trailer. It's too heavy (4 t vehicle + 0,8 t scissor). The power of the Brokk 330 and the 800 is the same. The only difference is that the 800 can move further" (1:15) [Alex]
- You like working with the Brokk 330? "Yeah I love it! You feel so powerful when you do this" (4:30) [Alex]
- Controlling the robot: "After a few hours you get the hang of it but it's harder than it looks actually. The Brokk 330 is actually really good, it's not so fast in the movements, the smaller robots are faster in the movements, so you have to have more precision. So, it's actually easier to drive a big robot than it is to drive a small one" (5:00). You can adjust the speed of the movements but the hammer slows down as well so you wont get the same effect. [Alex]
- With a robot You loose the feeling. It's a machine and you have 2 joysticks in your hands so you can't feel the feed force. [Pär]
- The Brokk should be 3 times as good as the Hilti 1000 at least! [...] 4 or 5 times as much power as the Hilti. You must almost believe that something is wrong with that one. It's not installed correct. [Olof]

Trolleys
- "The trolleys are too clumsy, because you have to move a lot, you hit it in different angles, you break, and the machine is often moving all over the place [...] if you have it on wheels it's not so effective. If you are going to hit one point. It's okay but the reality is not like that" Peter

Chisels
- The most common chisel is the "flat mejsel". The pointy one have a tendency to just go down. The wider ones are hard to get into the surface and those are used for tiles and the bumps.
- Chisels are stored in the case. Sometimes they transport the breakers in the case or they just carry it. Depends. Don't use the transport trolley.
SUMMON UP DESIGN DIRECTIONS

Supportive Robot

- Could you imagine a robot that you control with your arms/body but the movements would be really easy like the power-steering in a car? "It's hightech stuff. Maybe I don't know. It's hard to say when you don't really see it in front of you. It's hard to imagine how it would work in the field but...?" [Markus]

- Power-steering? "For me the small sticks are perfect because you have the sensitivity, you can do very small movements, if you get bigger maybe it gets more 'twitchy'? (17:45). (He has a hard time imagining how the 'power steering' would be like, but he will rule out that it could actually work. Actually I'm not quite sure he understands what I'm talking about) [Alex]

- Opportunity? "I think you should look at the machines how they are now and see if you can make them lighter or somehow easier to use for the body. When they come here to rent they just want the simple tool, because it does the work and it's often just a 2 hour job. Don't make it too complicated! Keep some parts of what it actually is. You need to see what you are actually doing sometimes" [Johan]

- (Harness) the important thing is of course that it's not limiting you, preventing your work task and I think that is the key. As long as it's not preventing you from reaching something, moving yourself or anything like that of course it's good.

- I think it's important to get rid of the breaker, if you need to pick something up, you need to go to the toilet or do something quick. Just throw it where you are digging, get a wrench, connect something, change tool, the chisel, shut off the compressor [Pär]

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- It cannot be difficult to put on the body. People would think it's too difficult to use it. [Pär]

- When people put on something like this people will start to laugh. If it looks like a fighting robot, transformers or something like that, it might be easier. [Olof]

- (Exoskeleton) For the military maybe it cost like a million and it's okay for them but maybe not in every day construction. [Olof]

- Autonomous machines? "Yeah, it's definitely in the future. I know in Kiruna men are drilling like 1000 meters under ground with the drilling rigs, but now the run it from above the ground with remote" (21:30). "It seems like the future is going more towards autonomous machines, lifting the weight off the body" (27:00) [Johan]

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Compact Robot

- Could you imagine a robot being even smaller than a Brokk 40? "Yeah why not, it's just that you have to get the power in it too. You can't use something with less power than a Brokk 40, nothing would happen. The problem is to have the robot small and still have the strength to break" (26:50) [Markus]

- How important is it that it's compact? "It depends what you are going to break. If it's a big wall then it doesn't have to be so compact, but if you want to get into an apartment with 90 cm door then you need a little machine". (28:45) The size of the space and the access to the space! [Markus] • Could you imagine a robot smaller than the Brokk 40?

- Imagine a robot smaller than a Brokk 40? "No, no, no. The size is good you can climb stairs with it so it's perfect, but the power is too little. The Brokk 50 is the same size but power is a gigantic difference. If you go any smaller it wouldn't be useful because the hammer on the robot has to have some effect and I believe if you make it smaller you loose the effect. Maybe if they develop very small hammers you could use small robots as well? The Brokk 40 is pretty much the same power as the TE 1000" (6:40) [Alex]

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SUMMON UP

DEVELOPMENT DIRECTIONS

like the one they are currently working in, but it's not very common for Umeå. "If you look at it world-wide it's a pretty good idea actually" (11:00) [Alex]

• With a robot You loose the feeling. It's a machine and you have 2 joysticks in your hands so you can't feel the feed force. [Pär]

• The power of smaller robots could be improved quite easily. [Olof]

• The manoeuvrability is of course one task, if it's very sensitive work — saving a pipe and take the concrete away around it — it's not so easy with a robot. And of course you can improve the steering system. Maybe you know when doctors make hard operations they have some glove more or less they put on and (do tiny movements with large hand gestures). [Olof]

• Pär talking about remotely controlled robots for swimming pools with asbestos, keeping the user in safety.

• In wood there is some frame detector scanning for density that could be used for pipe scanning.

• The technology for robot, I don’t think it’s so expensive, because you have the X-bot and Kinects. The technology is there, rather cheap. [Pär]

• We don’t make the carrier we make the breakers. Brokk made a carrier for hydraulic breakers and our bigger breakers are for excavators and so on. We don’t make the whole system we only make. So maybe it’s hard for us.... They put out tools on the machine. [Pär]

• The line between exoskeleton and remote robot is maybe not that straight. It could be something in between. [Olof]

• Of course you can’t mechanise small tasks, renovation, rebuilding, more than to a very limited extend. There is a limit where it’s not feasible, practically or economical to do that [Jan]

• I think we have chosen another route which is to bring down the weight and to bring down the vibration exposure as much as possible for the operator because that’s what makes his work easier. Then he is not so much a positioning device as more a user, because if you turn the operator into a positioning device then he is having a tough time. [Jan]

• They have tried to put in a handheld tool fixated to something that is used as a pedestal for the tool to do the work and I have not seen a single one that has been workable in a real environment. It must be very easy to handle to make it work. [Jan/Thomas]

• Would you see the value in a machine that is only for floors but really effective at it and then being more compact? "I don't think it's possible to make, because you still need to have this arm and you still have to break with it, like the hand machines (can't just go straight down, because nothing will happen), but if it’s possible to use it, yeah why not? (27:30) [Markus]

• Just for the floors? “Yeah, that would be awesome because we have hundreds of tons of floor down stairs, if you just type something in and it goes from wall to wall like a robotic lawn mower, but I think it’s a long way there.... I don't know how far they are with technology” (1:40) [Alex]

• You should never say never. There have been a number of trials to make cheaper, smaller and simpler tools for this, and so far a lot of good people have tried but none of them have succeeded, but some day maybe somebody comes up with something that works. I’m not so optimistic. But then again if you do something that is very little and can do the job, well fine I would be more than happy to see that”

Specialized Tool

• Batteries

For small drills and things like that it became more popular. I don’t know about the future of course, but nowadays we need quite a lot of power 1000-2000 watt or something like that, and with todays technology that would take quite a big battery pack to manage that. It’s not impossible but today it has quite a lot of limitations as I see it. [Olof]
SUMMON UP  SALES PERSPECTIVE

Markets

- The market is most caring about this is United Kingdom. They have a quite hard safety and health department that is really looking into this. They are in the front line of ergonomics. [Olof/Thomas]

- Sweden is not a very big market for us with this type of machines. In Sweden most of this work is happening with rig-mounted machines, which is not really the case to that extend in United Kingdom. [Olof]

- I don’t know how many percent tools we are selling in Sweden but I would say hardly none. Maybe 1%? At least 50% of our tools are sold within the EU. Germany, United Kingdom, France are the biggest. [Olof]

- In Scandinavia they stopped with pneumatic tools in the early 70’s and went over to more mechanised rigmounted solutions. [Olof]

- It has very much to do with tradition also, the market is very conservative. Maybe the northern countries are less conservative? The most conservative is the one in the US. They prefer the machine that grandfather bought. It should look like that not come with anything else that’s what we are used to use. Please give us that! [Olof]

- My personal view is that electrical machines will take more market shares [Thomas]

- We don’t have electric tools. It’s a very big market to grow in. I think we need to have electrical versions of the breakers [Pär]

- And of course the competitors of the electrical breakers, they are very aggressive [Thomas]

- It’s a strange market because Sweden used to be a market where vibration and performance were high value items and now they are going for the worst solution there is on the market [Jan]

- Biggest markets? ”North America. Certain countries in Europe. The Middle East. That’s the bulk of the tools but they are everywhere — bigger and smaller amounts. If you look at pure numbers the big numbers are in China, but those tools look totally different and they don’t have the same life cycle or anything like that so, it’s not really comparable. You take 6 of their tools and it won’t last longer than one of ours. [Jan]

- The Scandinavian market isn’t particularly interesting for several reasons and one is pretty good — the Scandinavian market has mechanised quite a lot. Mechanization is a good thing when it comes to heavy tasks, so there we are selling hydraulic attachments for small mini excavators or Brokks. If you see a Brokk there would be an Atlas Copco hammer on it. [Jan]

- In general we are a little bit smaller in Scandinavia than we should have been, on the other hand it’s not really a focus market. [Jan]

- What we have developed the last 4-5 years are vibro-reduced tools, that are lighter than used to be the case 20 years ago, and with the good performance of a pneumatic tool instead of the not so good performance of an electric tool. So we have targeted the markets that are conscious about vibrations, which is an increasing number of markets, including Scandinavia of course, with a group of tools which is much better than what have been in the market earlier. [Jan]

- The only problem is that in Scandinavia to get acceptance of these tools, because people are not used to look for these tools anywhere else than the electric tools market, but we do see an increasing number of tools going into Scandinavia, but it’s still low numbers relatively. That’s probably not because the tools are not good enough because they are. It’s because they are not familiar with pneumatic or hydraulic tools since 30 years. [Jan]

- If you look at Sweden, Norway, you will see that people are SO into electrical tools that they don’t see any alternative. They don’t look for any alternative because that’s what they think is there — and it’s a big task trying to turn that. [Jan]

- But slowly the more professional ones having tougher tasks they are starting to look for other things because productivity is so much better and we actually have a better vibration level

- In Sweden for some reason people turned away from pneumatics when the electric tools came. In a way it was considered to be old fashioned, but it also very effective/efficient and I think they are missing out on something there. Now we are slowly seeing that the number of these vibro-reduced pneumatic tools is growing so I think we are coming back but we are never going to be anything like the number of electric tools sold in the market, because there are many applications where electric tools are a practical choice. I mean if you have a 5 min job, why should you bother to bring the equipment for
something you can do with an electric tool in 5 min, but if you have a tough task and you want to finalize it with less vibration exposure to the operator and quicker, then of course the pneumatic tool is a very good choice. So the heavier the job the more the chances are that people will go and look for pneumatic. [Jan]

- No new user groups are being added. More and more market groups are being added, because 10 years ago you would still see people be doing this by hand with a sledge hammer. In India and Africa you still see people doing these jobs with other tools. What happening is that you have a spread of this type of technology into new markets, where it’s replacing older methods. [Jan]

- The total market is still growing in the world, but it’s growing mainly outside the industrialized countries. The industrialized countries market is rather stable. [Jan]

- Is the market going towards the work being handled by robots? "If you look at the heavy applications, yes. If you look at big demolition sites you will use hydraulic attachments one way or the other." [Jan]

Buyers/Customers

- In many cases the one who buys it just want the lowest price. They don’t care about the operators that much. It’s very seldom the buyer that is the user. [Olof/Thomas]

- A typical customer in the US is a rental company. They rent out the machine for 5 days and it come back. The only thing they want to do with the machine is clean it and send it out again. They don’t care about the vibration. They don’t care about the efficiency. If the performance is quite low, it can stay out another day. It’s even better for them! [Olof]

- The worst for them is if the machine breaks down. If it breaks down in the middle of a work task the operator is not very satisfied having to go back and get a new machine, so the durability is extremely important for many customers. They should also be easy to maintain in case it’s needed. [Olof]

- The rental companies don’t care about that (efficiency), because they are interested in renting the tools out as many hours/days as possible, so them it’s not a problem with productivity really. What ever the operator ask for he will get and if it happens to be a tool that will take 3 days to do what could be done in one day they will be happy about it, I think. [Jan]

- We are working both sides of this market — the Brokks robots and tools for lighter jobs that still need to be handheld [Jan]

Price

- The average life cycle of an electric breaker is not very long. It’s a tool you always risk to burn out if you overload it and if you have a tough job for it you will wear it — so they will need servicing. You won’t expect 10-12 years coming out of a tool like that. So the buying price you can’t set up against a set of pneumatic tools and a small compressor. The tool will last 7-10 and the compressor longer than that, so you have to take more or less the cost of ownership into consideration when you look at these things — life time costs and the cost per year, because if you just look at the price tag you are going to end up with the wrong conclusion. [Jan]

- The average life cycle of an electric breaker is not very long. It’s a tool you always risk to burn out if you overload it and if you have a tough job for it you will wear it [Jan]
SUMMON UP General Insights

Where

- “If you look at the time you use the machine it’s mostly on the floors, not so much on the walls” Markus
- “The floor is pretty easy... For the shoulders [compared to the walls]” Peter
- The breaking I saw in the elevator shaft was a good example of a place where they couldn’t use a robot. It would take too much time and it would be impossible to get the robot on the scaffold. [Markus]
- They have never used a Brokk in an apartment, then they use the TE-1000. The Brokk takes up too much space in a bathroom and “you have to be pretty steady on your hands so you don’t break the toilet or the stuff in there. You can get some marks from the tires too” (29:45) [Markus]

Who

- The builders putting concrete on the floors often have problems with HAVS because they use the breakers so often to remove the concrete that get outside, making the floor smooth/straight. [Markus]
- No one in Markus company has any problems with HAVS because they often use the robots. They only use the Hilti’s when they can’t get there with the robots.
- 99% of the people that rent tools/machines are professionals [Kenneth]
- Who is renting the machines? “From the big businesses that run through out Sweden to your local business guy that wants to do something at home. It’s mostly professionals, I would say about 95%” (0:45) [Johan]
- “I wish I had the energy and the brain to study, but I just don’t know what I want to be”
- Sometimes you didn’t use the gloves at all, why? “I’m lazy! The gloves are very expensive (700 SEK) so you can only have them on when you are operating the machine and you don’t want to take them on and off all the day. They break almost immediately” (6:10) [Fredrik]
- It’s not so common to break a whole floor like 20 cm thickness, often it’s bumps (spilled concrete) that you make [Markus]
- In private homes it’s mostly bathrooms, not big floors. [Alex]
- What are the TE-1000 used for? “It’s a pretty broad spread. I would say bathroom floors. That’s the most seen. (2:00) [Johan]

Economy

- 2 guys used 1,5 weeks to carve out the floor in a big room. They were working all day every day. They where looking at a Brokk, but the price difference was pretty big and they found it too expensive (2:30) [Johan]
- ’We have a very bad salary. We don’t make much money on this, so we are happy for every hour we get. We are in a different union than the carpenters’
- ”It’s just a shame that everything is so expensive. Maybe we have to break this one so we can get a new one” (11:30) [Fredrik]
## COMPETITORS

### BREAKER SPECS

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<th>Power Source</th>
<th>Type</th>
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<th>Vibro-Reduced</th>
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<td>TEX 180PS</td>
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<td>Impact Rate (blows/min)</td>
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<td>Brute 2</td>
<td>HM1810X3</td>
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### Power Source Specifications

#### Power Source

- **Type**: Pneumatic
- **Brand**: Atlas Copco
- **Model**: Cobra Combi
- **Weight**: 25 kg
- **Impact Rate**: 1600-1800
- **Vibration 3-axis (m/s²)**: 4.5
- **Exposure Action Value - EAV (min)**: 25
- **Sound Pressure Level (dB)**: 96

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### Power Source

- **Type**: Petrol
- **Brand**: Atlas Copco
- **Model**: Cobra Pro
- **Weight**: 25 kg
- **Impact Rate**: 1600-1800
- **Vibration 3-axis (m/s²)**: 4.5
- **Exposure Action Value - EAV (min)**: 25
- **Sound Pressure Level (dB)**: 96

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### Power Source

- **Type**: Electric
- **Brand**: Hilti
- **Model**: TE 3000-AVR
- **Weight**: 29.9 kg
- **Impact Rate**: 860
- **Vibration 3-axis (m/s²)**: 7
- **Exposure Action Value - EAV (min)**: 25
- **Sound Pressure Level (dB)**: 94

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### Power Source

- **Type**: Electric
- **Brand**: Bosch
- **Model**: Brute 2
- **Weight**: 29.5 kg
- **Impact Rate**: 900
- **Vibration 3-axis (m/s²)**: 7
- **Exposure Action Value - EAV (min)**: 25
- **Sound Pressure Level (dB)**: 70

---

### Power Source

- **Type**: Electric
- **Brand**: Makita
- **Model**: HM1810X3
- **Weight**: 32.3 kg
- **Impact Rate**: 1100
- **Vibration 3-axis (m/s²)**: 7
- **Exposure Action Value - EAV (min)**: 25
- **Sound Pressure Level (dB)**: 107

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### Power Source

- **Type**: Electric
- **Brand**: Dewalt
- **Model**: D25980
- **Weight**: 31 kg
- **Impact Rate**: 900
- **Vibration 3-axis (m/s²)**: 7
- **Exposure Action Value - EAV (min)**: 25
- **Sound Pressure Level (dB)**: 93
TECHNOLOGY SENSORS

CLASSIFICATION

1/ WHAT IS MEASURED

Proprioceptive (PC) Sensor
- Measure values internal to the robot system
- e.g. motor speed, wheel load, heading, battery status

Exteroceptive (EC) Sensor
- Gives information from the robot’s environment
- e.g. distance to objects, light intensity, unique features

2/ MEASUREMENT PRINCIPLE

Passive sensor
- Energy coming from the environment
- E.g. camera, microphone

Active sensor
- Emit their energy and measure the reaction
- Better performance but some influence on the environment
- E.g. laser scanner, sonar sensors

ORIENTATION

An small orientation error will cause a large position error as the robot moves.

Compass
- Available as solid state devices that measure the 3D magnetic field. This gives the rotation of the robot up to rotations about “north”
- They give absolute rotations rather than relative (incremental). This means accumulation of errors can be limited.
- They require careful recalibration every time the robot is opened up.
- Even degaussing may be needed.
- Batteries and motors cause the most problems.

Gyro (rate gyro)
- Measures rotation speed
- Must be integrated to get orientation
- Errors accumulate and drift over time.
- Best ones are fibre optic gyro (expensive and relatively large)

Inclinometer
- Measures angles of slope (or tilt), elevation or inclination of an object with respect to gravity

Accelerometer
- Measures linear acceleration
- Protects hard drives, activates airbags, etc.
- Typically filtered to extract the direction of gravity. Thus giving the rotation up to rotations about “up”.
- It is hopeless to try to integrate a low cost accelerometer twice to get xyz estimates.
- Often packaged with gyro

And GPS e.g. Xsens MTi-G (even has a barometer)

RANGE SENSORS

Very common for estimating position. Several principles can be used.

Time of flight
- Measure travel time
- Speed of propagation, c, distance d and time t
  \[ d = ct \]
- Travels back and forth, i.e. time for two trips
  \[ d = \frac{ct}{2} \]
- Speed in air
- Sound: 344 m/s at 20°C
- Light: 299,792,458 m/s

Phase difference
- Measure phase difference between reflected beam and the transmitted signals

Triangulation
- Use simple geometric relations to recover depth
- Example is IR/laser triangulation
- Can be implemented with PSD (position sensitive device)

TACTILE

- Bumper switches
- Light
- Non-contact proximity sensors
- Capacitive sensors
- Inductive Sensors
**SONARS**

- Send out sound pulse and measure time until it comes back
- Very common on robots
- Sound is very slow in air (343m/s at 20°C)
- Reflections cause false readings

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**SENSORS**

**Sonar**

- Send out sound pulse and measure time until it comes back
- Very common on robots
- Sound is very slow in air (343m/s at 20°C)
- Reflections cause false readings

**IR Ranging**

- Two common principles
  - Intensity (very sensitive to reflectance)
  - Triangulation
- Quite inexpensive and easy to interface
- Close range obstacle detection

**IR Scanning - SICK**

- Rotating mirror (75Hz)
- Pulsed laser (higher power, less energy)
- Long range (up to 80m)
- Accuracy 1cm
- Samples with 1°
- Often used in interlaced mode (combine two scans shifted 0.5°)
- Safety classified
- Expensive: 40,000SEK

**IR Scanning – Hokuyu URG**

- Smaller and cheaper
- Shorter range : 5.6m
- More models available

**Radar**

- Radar = Radio Detection And Ranging
- Transmit and receive radio signal
- Many materials do not absorb / reflect / scatter much of the signal » long range
- High conductivity » strong reflection
- Get range and direction to multiple targets

**Radar Apps**

- Used heavily in aircraft industry and the military
- Now finding its way into cars and trucks
- ACC : adaptive cruise control

**GPS**

- Time synchronization
  - Atomic clocks on each satellite
  - Monitoring from ground stations
  - Ultra-precision time synchronization extremely important
  - Position accuracy proportional to precision of time measurement
  - Light travels 0.3m per nanosecond
  - Simpler clock in the receiver
  - Needs to receive signals from at least 3 satellites to calculate the position and 1 additional to get the altitude. More satellites gives better accuracy.
  - GPS is now widely spread technology

**Global Positioning System GPS**

- Developed for US military use
- Now accessible for commercial and private applications
- There are 24 GPS (NAVSTAR) satellites orbiting the Earth every 12 hours at 20200km altitude
- Location of the GPS receivers are determined through time of flight and triangulation
- Challenges
  - Time synchronization between satellites
  - Real time update of exact satellite positions
  - Precise measurement of time of flight
  - Interference with other signals

**Differential GPS (DPGS)**

- Correction with local reference information
- Local station coverage 100m-3km
- Accuracy in the order of a meter

**RTK-GPS**

- Network of base stations with accurately known positions (ca 70 km apart)
- GPS receiver with radio (e.g. GPRS)
- Sends approximate position to server
- Gets local corrections from server
- Can get cm accuracy
- Used in civil engineering applications, e.g., building roads

(Source: Service Robots, John Folkesson 2010)
COMPUTER VISION
- Cameras come in many prices and sizes.
- Cameras give lots of data.
- There is also lots of information but one must work to get it.
- Many vision algorithms have been developed.

CALIBRATION
- To remove distortion one must calibrate the camera.

Wide-Angle Cameras
- Normal camera rather small field of view
- Larger field of view with
- Wide angle / Fish-eye lens
- Omnidirectional camera with mirror
- Image distorted

IMAGE DEPTH
- Some applications can work with raw image, some require undistortion

Stereo Vision
- Distance given by baseline, focal length and disparity (difference in image position)

Transform left image to the right image assuming planar floor
- Compare to real right image
- Difference violates planar assumption obstacles

3D RANGER CAMERA
- Also known as RGB-D
- Combines images (RGB) with depth (D)
- Two main techniques: Structured light with stereo and Time of flight

Structured Light
- Finding correspondences in images is hard
- Idea: Project your own light pattern on the scene
- Ex: Can be used as obstacle detector (obstacles will deform the projected lines of light)

Swiss Ranger
- Swiss Ranger gives 176x144 images with range information.
- Price: ≈$9000
- Modulated IR light, camera measures time-of-flight in each pixel
Microsoft Kinect
- A depth camera for the Xbox 360
- Significant decrease in price $150
- 30fps,
- 640x480

OBJECT RECOGNITION
Typical Approach
- Extract feature points in training image
  » model
- Extract feature points in new image
- Match new points to model » recognition

SIFT Scale Invariant Feature Transform
- Most used feature today in robotics

VISUAL ODOMETRY
- Can use image data to estimate how the camera is moving » visual odometry
- Stereo or mono
- Can be quite accurate

SLAM
- Simultaneous Localization and Mapping
- The robot builds a map while localizing on the map.

1) Place recognition using vision and saved place images
2) 'Scan Matching' raw scans are the map.
3) Use a map of distinctive features found in the sensor data.

(Source: Service Robots, John Folkesson 2010)