FUSE Application Experiment 29392
Dissemination / Demonstrator document

INTELLIGENT AUTONOMOUS STEAM TRAP SYSTEM
Microcontroller and sensor to save steam energy

Abstract description

Purgadores de Condensado S.L. is an 8-employee Spanish company involved in the design and manufacturing of mechanical steam traps since 1986, and having a turnaround in 1998 of 640 KEUR. The steam trap manufactured before this Application Experiment was purely mechanical, so the company never used electronic technology before this AE. The company belongs to the industrial sector NACE 2913: Taps and Valves.

Steam traps are automatic valves widely used in systems that use steam energy. Their function is to eliminate water condensation in steam lines and equipment without leaking steam and energy. They are sold to many industries, but mainly to petrochemical plants and oil refineries.

Leaks in steam traps are a significant source of losses in petrochemical industry. Manual, expensive surveillance has to be used in order to detect the valves malfunction as early as possible. The problem is aggravated by the very big number of these devices that can be installed in a typical plant (thousands), so when the failure is detected the valve may have been causing losses for a long time and causing a further wearing of the internal parts of the valve. This is the reason why an electronic early detection system represents a big step forward in this industry segment.

This Application Experiment has developed an Intelligent Autonomous Steam Trap (IAST), capable of self-monitoring its own operation, detecting immediately any type of failure, thus providing a significant advantage to the end user in terms of savings in energy and maintenance costs. This has been attained incorporating electronics for the first time to the classical mechanical design. The technology used has been a microcontroller.

The project took 24 weeks, and its budgeted costs until prototypes were 60 KEUR. Additional prototyping costs i.e. mechanical modifications on steam traps to implement this new concept have reached 57 KEUR, so the total costs of the prototypes were 117 KEUR. Industrialisation costs to bring the product to the market will take 82 additional KEUR. The company expects the total investment of 199 KEUR to be paid back in a period of 36 months, with an estimated ROI of 150% after 4 years of product life.

The company intends replicating its AE for providing RF transmission capabilities and computerised control for a next version of new and more powerful IASTS.

Keywords and signature

Microcontroller, steam traps, valves, ultrasound, solar cells, power consumption, petrochemical industry.

Signature:

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1. Company name and address:

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Fax: +3491 404 4875
Contact Person: Vicente Blázquez

2. Company size

Purgasa is a small (8 employees) independent company, operating at their single location in Madrid. As it happens in many small companies, some functions are simultaneously implemented by the Management (purchases, sales and exports, R & D, management, etc). The company patented the bimetallic steam trap in 1986 and the variation monoblock in 1997, marketing its products and services only within the Spanish market. Its sales revenue was of 640 KEUR in 1998.

3. Company business description

Purgasa is involved in the design and manufacturing of mechanical steam traps since 1986, including predictive and corrective maintenance of these types of valves. Maintenance services account for app. 15% of the company's revenues. The company belongs to the industrial sector NACE 2913: Taps and Valves, and was a purely mechanical company before this Application Experiment.

The function of the steam trap is to purge the condensed water from steam lines and process equipment, so it is taken back to the boiler, but keeping the steam in the 'live' pipes. The company produces four different types within the family of bimetallic steam traps, i.e types Magnus, Monoblock, Classic and Bitherm. This last type (bi-thermostatic) is the most popular and advanced steam trap, which is being used in the most important Spanish oil refineries, chemical industries and power generation plants, and represents 75% of the sales of the company.

4. Company markets

The activity of the company is exclusively in the field of steam traps. These elements are commonly used in a great variety of industries, however due to the small size of the company, PURGASA has been selling their products and addressing its strategy only for petrochemical industries and power generation in the Spanish market.

The total market of steam traps in the world is about 3 million units per year. European market can be estimated in app. 800.000 units per year.

The Spanish market of steam traps can be estimated in 20.000 units per year. It is divided in four technologies of traps: floating, thermodynamic, inverter bucket and bimetallic. The bimetallic are the most common in petrochemical and energy plants. Purgasa just operates in the bimetallic's market, selling 80% of its production to large industries, and the remaining 20% to small users and industries.

The bimetallic steam traps have a more reliable technology, and they can save up to 15% of energy due to their better design against steam leaking. They are also the most expensive in their size range, with a unit cost of around 120 EUR, 70% more than the cheapest type (thermodynamic). Due to this important price gap between thermodynamic and bimetallic, the bimetallic type addresses the high-end segment of the market, where product's quality is the main issue. The share of Purgasa is app. 15% of this market.

The Spanish market of bimetallic steam traps for large industries has an annual turnover around 3,2 MEUR, and is growing at an app. yearly 9%, more or less the same as in the rest of the world. This can be broken down into two elements: replenishment and new installations, accounting each one for 7% and 2% respectively, since the bimetallic steam traps constitute nowadays the 40-50% of the total installed in large industries, but they will likely reach the 70% of the total installed in 10 years.

This growth is driven by the increase in environmental consciousness, and the ever-stronger regulations on environment protection at the factory itself and at the product level, forcing the development of new and cleaner products and processes in petrochemical industries. Thus being able to clearly provide energy savings will constitute a clear advantage and an opportunity to get a bigger share of the market.

4b. Company competitive position at the start of the Application Experiment

The competitors in this market produce all of them abroad of Spain, except Purgasa and Spirax Sarco, the latter just a small fraction of its total sales in Spain. The figure below shows the different competitors market shares:

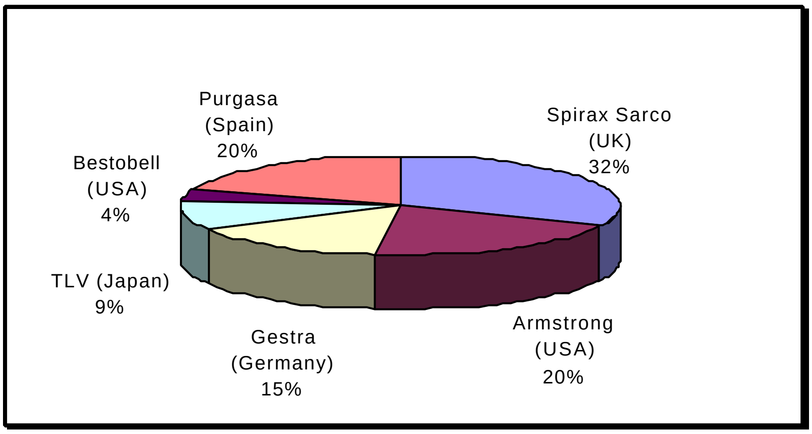


Fig 1. Spanish shares of bimetallic traps for large industries

The technology used by the other manufacturers is mainly mechanical, but economies of scale make these bigger companies able to offer cheaper prices, in some cases up to 20% less than the average price of 120 EUR per unit. The main advantage of Purgasa is being local and thus able to get a better communication with the customers to know their specific needs and to offer a closer after sales service. But this is proving not to be enough, as the company has suffered a decrease of about 15% in its sales during the last two years, and this trend could continue unless specific actions are taken (see historic sales chart in fig. 2).

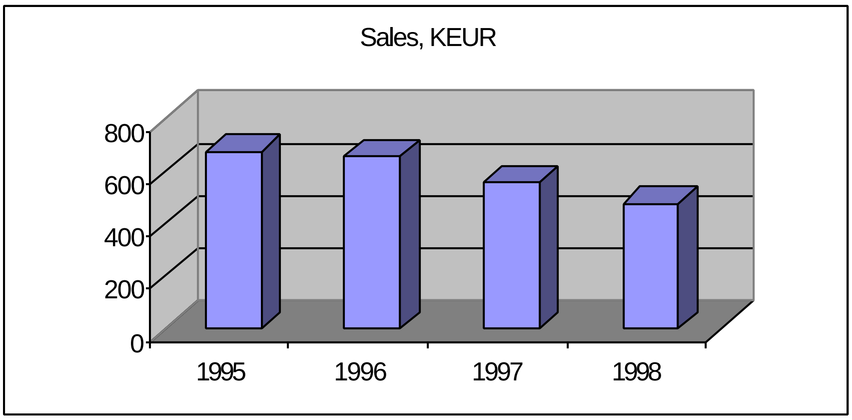


Fig. 2: Sales history

The company was thus very interested in the FUSE innovation, because it could provide the necessary breakthrough to expand its Spanish market share and also to entering in the international market by offering a well-engineered product.

5. Description of the product to be improved

Steam traps are automatic valves widely used for controlling steam energy. Their function is to eliminate water condensation in steam lines and equipment without leaking steam and energy, purging automatically hot condense water and closing tight to steam.

Steam traps are necessary for a wide list of applications: drip legs, tracing lines, heat exchangers, process equipment, turbine protection, air heaters, storage tanks, ejectors and vacuum equipment, steam atomiser equipment, and many other. The existing product is commonly used on a very wide range of industries and environmental conditions but petrochemical industries are the biggest steam trap users (for example, chemical plants have from 1.000 to 10.000 units and oil refineries have from 5.000 to 80.000 units).

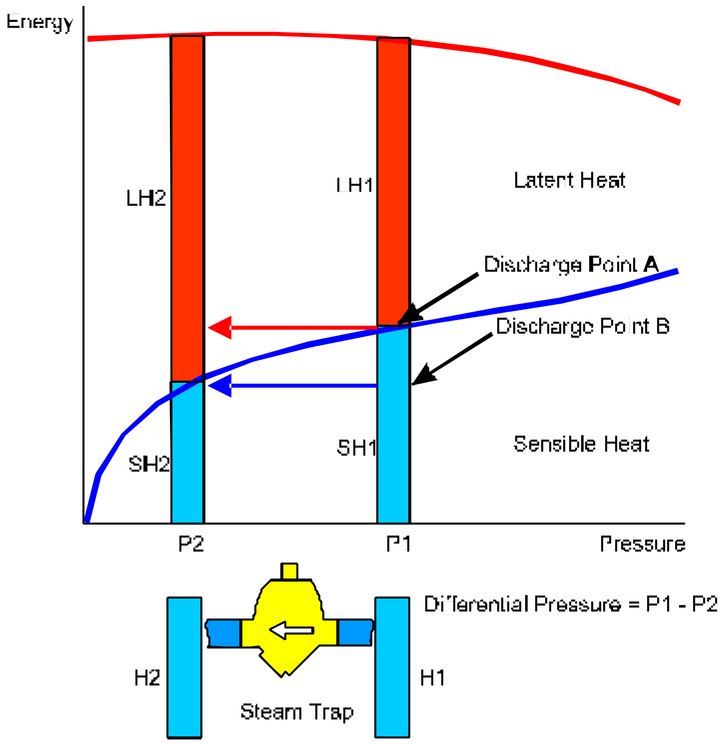


Fig. 3: Installation and operating principle

Fig 3 shows typical installation of a steam trap connecting a steam pipe (H1) and a condense water return pipe (H2). Steam trap operation is briefly described as follows:

The saturated or superheated steam (live steam) is used for heating process. Live steam becomes hot condense water after transferring its latent heat. Hot condense water reduces efficiency of heating process and has to be normally evacuated or purged as soon as it is formed, but live steam have to be retained during the purging process. This function is performed by steam trap. The Bimetallic steam trap performs that operation by means of bimetallic thermostat. When temperature of hot condense inside steam trap decreases then thermostat opens the valve discharging condense water.

Once condense water is discharged, the temperature inside the steam trap increases step by step and the valve slowly closes. Steam trap closes before live steam arrives to the valve avoiding steam loss and energy loss. *Open steam trap failure* is produced when the steam trap does not close tight to fully retain inside the live steam and the steam trap leaks live steam through its internal seat valve.

Condense discharge through steam traps still contains 1/5 of the steam energy. For that reason it is returned to the steam generator (boiler) where it is evaporated again. Steam leaks through steam traps increases back pressure in condense return lines. This in turn highly affects the steam traps increasing steam leaks. Even supposing a small leak of energy by any steam trap, the amount of energy loses is enormous because of the huge number of steam traps in operation.

For the above reason steam traps are considered one of the problems to be urgently solved in any industry. Inspection departments periodically perform very expensive manual inspections to detect failures and leakage in steam traps as early as possible.

The bithermostatic steam trap (fig. 4) is a reliable and flexible device, operating through bimetallic thermostats and with the following functional features:

- Wider differential pressure range
- Balance pressure valve (useful life three times longer than normal valve)

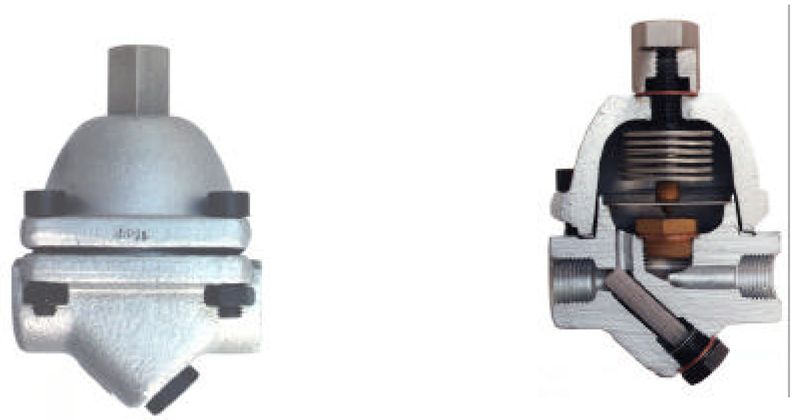


Fig. 4: Bi-thermostatic steam trap

- Valve is not affected by dirty condense
- External adjusting device while in operation
- Independent seat and valve (80 % less expensive spare parts)
- Maintenance during normal operation without dismounting the valve

Moreover, the technical features of the steam traps are:

Body&Cover	Forged carbon steel, alloy steel or stainless steel
Seat&Valve	Stainless steel
Thermostat	Bimetal resistant against corrosion
Gaskets	Asbestos free (graphite/AISI 316)
Strainer	"Y" type or integral type
Operation pressure range	1 bar up to 215 bar
Maximal temperature	540 ºC
Sizes	15 mm to 150 mm
Connections	Threaded, welded or flanged (DIN or ANSI)
External adjusting device	Only in bi-thermostatic types

Reasons to innovate

Steam leaks detection and steam traps maintenance are two critical problems in large industries like petrochemical plants. These are the reasons to innovate the product, in order to achieve Improving efficiency, saving energy, reducing costs of materials and maintenance and reducing inspection costs.

In fact, the innovation of the AE solves the need of checking steam traps using a portable ultrasound leak detector. This procedure detects failures long time after they appear, leaking energy, increasing back pressure in condense return lines, creating very destructive water hammering effects and making very difficult residual energy recovery. The solution would be to inspect steam traps more often, but this is expensive. The goal of the new IASTS is to solve the problem by providing on-line surveillance and warning of trap failure.

6. Description of the technical product improvements

The objective of the AE was to implement the first Intelligent Autonomous Steam Trap of the company, able to self-detect its own failures in real time, reducing production cost, operation cost and maintenance costs and improving safety operation conditions in petrochemical installations.

Physical characteristics of the IASTS are mechanically similar to the normal steam traps, only adding an electronic device on top of the trap. The electronic device is connected mechanically outside the steam trap, thus converting a normal steam trap into an IASTS is straightforward, as will be shown in the following paragraphs.

The product developed in this Application Experiment is an ultrasonic electronic detector and analyser, self powered by solar energy and rechargeable batteries. The electronic device is based on a microcontroller, which efficiently handles all functions and operation of the device. The device may incorporate up to four different sensors to measure the correspondent parameters (ultrasound, temperature, pressure and/or conductivity). These parameters are the inputs to the microprocessor to perform the right analysis of the steam trap operation.

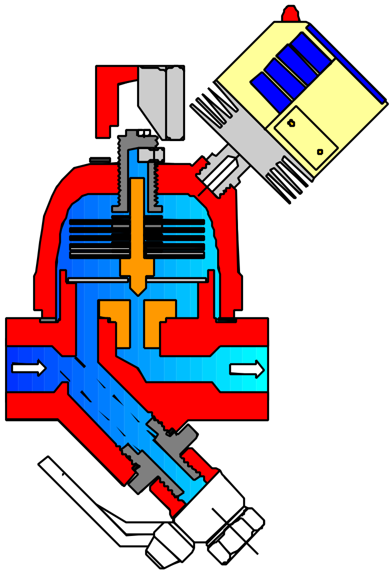
The temperature sensor detects close failure of steam trap. The open trap failure is detected by using an ultrasound sensor that senses the continuous ultrasound (in a range 40 kHz +/- 1 kHz) generated by the steam flowing through the malfunctioning valve. ‘Intelligent’ filtering is necessary to remove transient noises that could lead to false alarms.

As soon as any parameters don’t fulfil the right value, the microprocessor generates the correspondent alarm signal. The device supplies three optical alarm signals by blinking a high efficiency LED once, twice or three times every two seconds. Batteries must keep the alarm visible more than ten days.

Average current consumption must be between the values of more than 1,4 mA to ensure the optimum batteries exercise, and less than 4 mA to get autonomy enough for this application. Within these current values, batteries autonomy reaches one month in complete darkness and 4 years in day and night regular recharging operation. Current consumption control in surveillance mode assures the full exercise (one full discharge and recharge) of each battery pack every month, that is a condition of the batteries manufacturer to guarantee the maximum useful life of batteries.

The next picture shows a typical IASTS, which is composed of :

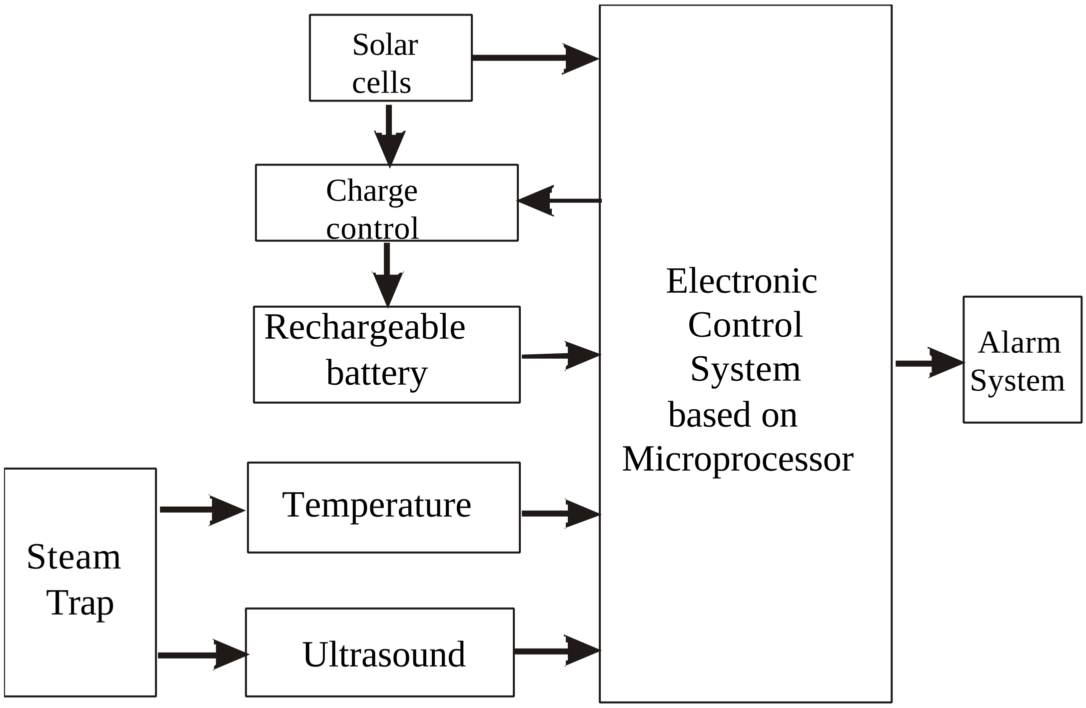
- One normal bithermostatic steam trap
- Two sensors (temperature and ultrasound)
- Autonomous source of energy (Ni-Cd solar rechargeable batteries)
- Electronic analyser based on microprocessor
- Alarm system



Intelligent Autonomous Steam Trap System

The electronic device developed by this AE (actual size) and the block diagram of the IASTS are shown on the next pictures:

Electronic device of the IASTS



General block diagram of the IASTS

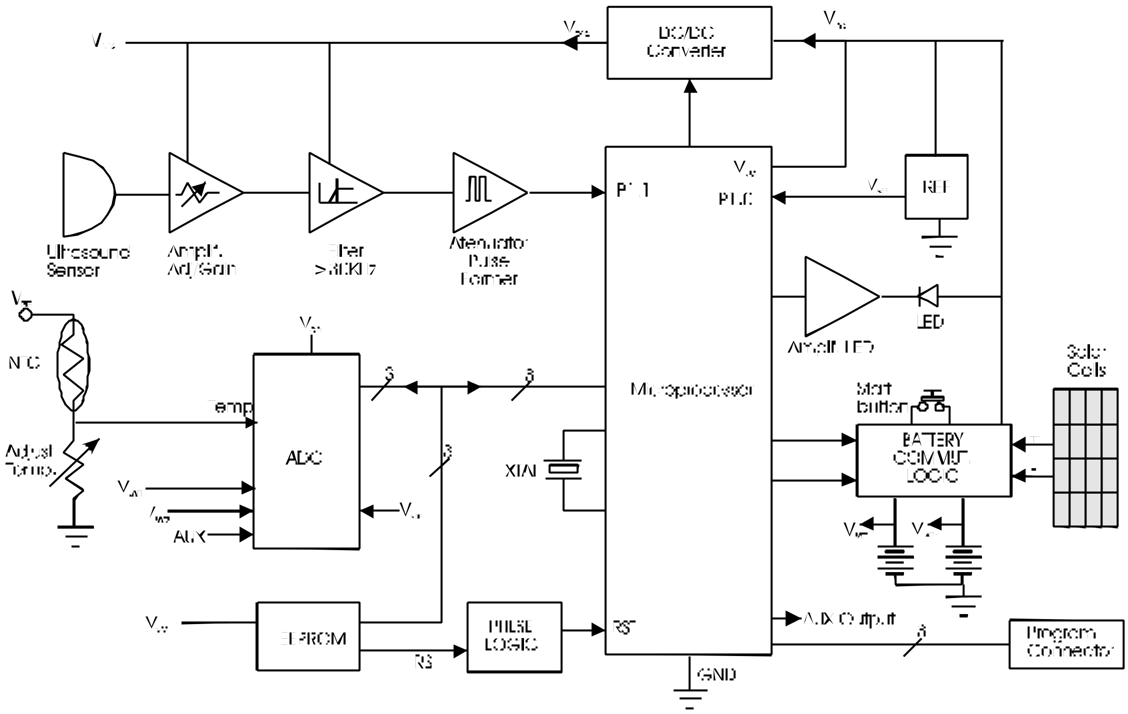
Most steam traps work at very high temperature, in the range of 80º up to 200 ºC. Microprocessors and electronic components can not support so high temperatures. For that reason electronics were properly protected against high temperature by means of an aluminium heat sink, which diverts the heat flow from steam trap outside the electronics. Maximal operation temperature for electronics will be limited to 85 ºC.

The aluminium heat sink ends in a threaded connection one side, which will be fitted by a threaded connection on top of the steam trap cover, and ends on a flat flange at the opposite side to fit a polycarbonate box to place sensors and electronics.

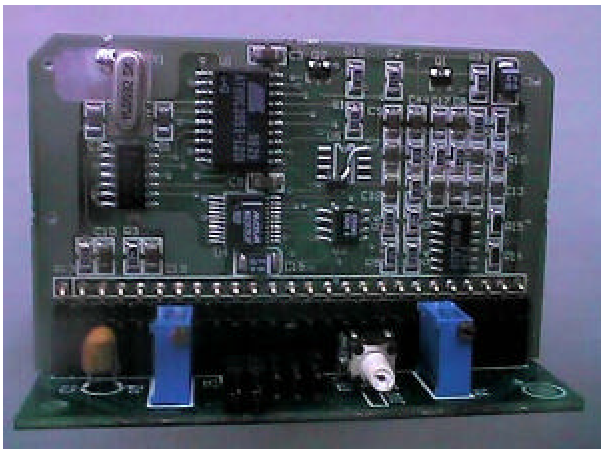
Flammability of external plastic box was designed according with UL (class V-0), resistant to most of acids and alkalis, which normally can be present on petrochemical plants. Electrical energy consumption is limited to 25 mWats, and electric and electronic components have been selected in order to get the approval of international organisms, for use in restricted safety areas in oil refineries (zone 0, class IIC). The equipment should be certified according to CENELEC, UN 50014 and UN 50020 norms under category EEX IA IIC T4.

The IASTS is powered by the combination of photovoltaic cells and rechargeable 3.6 Volts Ni-Cd batteries (3 cells of 1.2 Volts). Autonomy of batteries is 30 days in complete darkness and we expect life of batteries about 3 up to 5 years. Solar cells have been encapsulated to protect them from the environment.

Next figures show the functional electronic block diagram of the IASTS and a picture of the PCB.



Functional block diagram of the IASTS



PCB of IASTS

The ultrasound signal is detected by a piezo-electric transducer, sent to an adjustable gain amplifier to get the required level via AGC, and then to a high-pass filter to cancel signals under 30 KHz. The signal is then clipped to transform the sinus wave into pulses, and introduced to the microcontroller where it is compared with a reference signal and the AGC feedback signal is generated. As result of the comparison the microcontroller sent alarm signal to LED when the input ultrasound signal is higher than the reference value.

As a general rule, IASTS does not need to measure very precisely the temperature, but must detect when the temperature is lower than 60 ºC +/- 5 %. The temperature signal is detected by a thermistor NTC and sent to an analogue digital converter (ADC). The output of the ADC is sent to the microcontroller where the signal is handled conveniently for alarming when the temperature is lower than the trigger point value. The trigger point value can be modified adjusting the potentiometer.

An electronic circuit makes the switching between both batteries. The switch is handled by the microcontroller, which makes the supervision and maintenance of the batteries. Furthermore, an external port is allocated for testing purposes and future functions (programming), and an auxiliary output is foreseen for future applications as well.

Estimated price for IASTS will be twice of normal steam traps. However price is not significant for IASTS, but the feature of continuously detecting very expensive steam leaks during long periods of time without human assistance and saving in maintenance and energy.

7. Choices and rationale for selected technologies, tools and methodologies

The reason for choosing electronic technology complementing the purely mechanical used so far is quite obvious, as the detection of the different magnitudes and intelligent processing simply cannot be done mechanically. The choice of electronic technology is compelled by the inability of mechanical steam traps to self-monitor its operation. The electronic technology is able to meet the strongest reliability and durability requirements where the mechanical technology fails. Once the electronic technology was selected, the choices were discrete components, microprocessors, FPGA or ASIC.

During the first discussions with subcontractor and TTN, we have tried to discover what type of electronic technology would be the most appropriate to get our goal of designing the IASTS, entirely meeting our product specifications. The key point was finding the choice of electronics technology suitable to fulfil both the required functionality, power consumption, cost and reliability. A brief rationale for the choices made for the different elements and methods follows.

Discrete components and FPGA technology

Discrete components were discarded due to the complexity of the functions to perform and the large dimension that would be resulting with this type of components. In addition, the power consumption obtained with discrete components could be much higher than the maximum allowable by the electronic module. On the other hand, FPGA is more expensive than the relatively simple microprocessor used, and poses more difficulties to get the required power consumption control, which is very easy to control with the different power modes of the microprocessor.

ASIC

The last option considered was ASIC technology. This technology has not been selected by the moment due to the fact that this experiment will be extended in the future, by adding the capacity of transmitting alarm signals by RF. That could lead to modifications of the first version of the product, so we prefer testing the market with a more flexible option. However, the enormous application range of the RF product will make necessary to consider the ASIC technology for the future, specially when sales volume justify this technology. That would be part of the internal replication process as above already said.

Microcontroller is the choice

Microcontroller is the temporary right choice, because of the constraints explained to award the project to the ASIC technology for the time being.

ATMEL 89C2051 was selected among 8 bit microcontrollers because it incorporates low power consumption operation modes, flash memory which allows to make software changes easily, RAM memory, it has input/outputs enough for this application, “C” compiler is available also for this microcontroller, there are different packages and its is cheap easily available on the market.

Most important characteristics of ATMEL 89C2051 are:

- Compatible with MCS-51™ Products
- 2K Bytes of reprogrammable Flash Memory
  Flash Memory Endurance: 1,000 Write/Erase Cycles
- 2.7V to 6V Operating Range
- Fully Static Operation: 0 Hz to 24 MHz
- Two-Level Program Memory Lock
- 128 x 8-Bit Internal RAM
- 15 Programmable I/O Lines
- Two 16-Bit Timer/Counters
- Six Interrupt Sources
- Programmable Serial UART Channel

- Direct LED Drive Outputs
- On-Chip Analogue Comparator
- Low Power Idle and Power Down Modes

Another reason for this choice was that the selected microcontroller has three states (active mode, idle mode and power down mode). Idle mode and Power down mode are necessaries in order to adjust energy consumption to the required value.

Energy consumption of the microcontroller in every state is:

- Active mode: 3,8 mA
- Idle mode: 800 μA
- Power down mode: 2 μA

Cost is of course an important issue, and it is evident that IASTS will be more expensive than mechanical steam traps because of the ISATS is formed by the mechanical steam trap and additionally the electronic system, which performs the intelligent surveillance. But the increase in cost is widely compensated by the savings in the operation, as explained above.

Development tools
As the company had no previous experience on electronic or microcontroller design, the tools used were those available by the subcontractor i.e. a PC-based emulator for the design of the microcontroller's software and also PC-based design tools for the PCB layout. These were found powerful enough to do the tasks required in this relatively simple Application Experiment, and with a reasonable cost.

Test methodologies
The electronic module has been tested by laboratory tests and field tests. The laboratory test program has been generated by Tecnologia y Diseño, S.A. and field test by Purgadores de Condensado S.L. Final testing of the product has been carried out in several oil refineries in very hard actual conditions of operation.

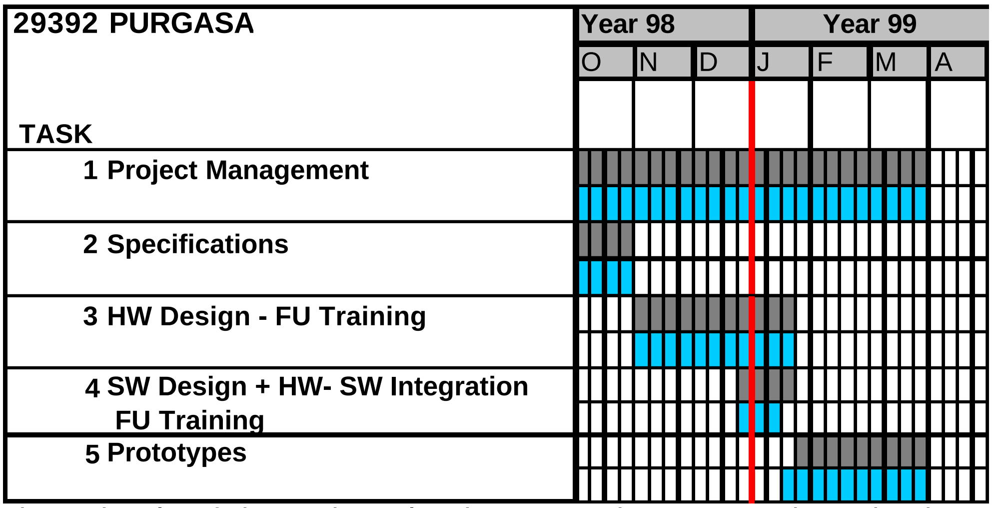
Reliability and certification to operate in hazardous atmospheres are most severe objectives to achieve, and the design, fabrication and test methodologies addressed directly to them from the beginning. Fulfilment with the CENELEC requirements and European norms EN-50014 and EN-50020 (for intrinsically safe conditions) mean severe electronic circuitry restrictions (low voltage, low current, low capacitance, low inductance, etc) and especial design for safety requirements. Conventional electronic design methodology has been used, with laboratory test and experimental verification.

8. Expertise and experience in microelectronics prior to the AE

The previous expertise of the company was purely mechanical and in fluidics, but no one in the staff had experience in electronics. The personnel participating in the project was the technical director, an aeronautic engineer.

9. Workplan and rationale

The initial work plan had a duration of 6 months. The actual (blue) versus the proposed (grey) work plan is shown in Gantt chart below. There was almost no difference between the two workplans, and the project was concluded without any delay.



The rationale of the project planning was using an experienced subcontractor to design hardware and software, being the task of the First User to specify, learn and control the results, helped by a second subcontractor. The project had the following tasks:

Task 1: Project management *Duration: 24 weeks*

Company effort: 28 person-days *Subcontractor 2 cost: 1 KEUR*

Management and follow-up during all the duration of the project. Performed by the technical responsible within the company, with the assistance of subcontractor 2, has controlled all the deviations of the project from the scheduled plan and budget. Also the preparation of progress reports and end report of the project for dissemination.

Task 2: Specifications *Duration: 4 weeks*

Company effort: 15 person-days *Subcontractor 1 cost: 3.2 KEUR*

Subcontractor 2 cost: 0.5 KEUR

T2.1.- Product specifications

This task formally defines the requirements of the microcontroller based product.

T2.2.- Design specifications

The objective of this task has been reviewing the selection of specific components, especially the microprocessor, and defining the functions to performed by the microprocessor.

The main effort was performed by Subcontractor 1. FU had to approve the final performance specified, helped by Subcontractor 2.

Task 3: Hardware design - FU training *Duration: 11 weeks*

Company effort: 20 person-days *Subcontractor 1 cost: 16 KEUR*

Subcontractor 2 cost: 1.5 KEUR

T3.1.- Hardware design of ultrasound and temperature detection system

This task produced a hardware design based on the selected microprocessor.

T3.2.- Analysis and testing of energy consumption

The objective of this task was to optimise the energy consumption in order to get an intelligent and autonomous energy management based on the microprocessor capability.

T3.3 - Hardware design of the solar recharge battery system

This task produced a hardware design based on the selected microprocessor. Again, Subcontractor 1 performed the main effort. FU had to approve the final performance attained, helped by Subcontractor 2.

Task 4: Software design + HW-SW integration *Duration: 3 weeks*
Company effort: 5 person-days *Subcontractor 1 cost: 8 KEUR*
Subcontractor 2 cost: 0.5 KEUR

T4.1- Software specification. Integration and testing of software and hardware
This task involved the writing, verification and testing of software, as well as its integration with hardware, in order to get the specified performances of the product based on the selected microprocessor. Subcontractor 1 performed the main effort. FU had to approve the final performance attained, helped by Subcontractor 2.

Task 5: Prototypes *Duration: 10 weeks*
Company effort: 40 person-days *Subcontractor 1 cost: 8 KEUR*
Subcontractor 2 cost: 1.5 KEUR

T5.1- Electric circuits and PCB's drawings. This task produced a PCB's drawings of the product.
T5.2 - Prototype PCB's manufacturing, mounting and assembling of one functional prototype. This task produced one functional prototype.
T5.3 - Final functional test
This task has involved the testing of the final prototpe in order to demonstrate its compliance with the specification. Tests have been made in laboratory with the help of subcontractors and in real operation conditions in the oil refineries of Puertollano, Algeciras and Huelva, by the FU alone.

Summary of real efforts and costs		**First User Pers.days**	**Subcontractor 1 KEUR**	**Subcontractor 2 KEUR**
Task				
T1	Project Management	28	-	1,00
T2	Specifications	15	3,20	0,50
T3	HW Design - FU Training	20	16,00	1,50
T4	SW Design + HW- SW Integration	5	8,00	0,50
T5	Prototypes	40	8,00	1,50
Total		**108**	**35,20**	**5,00**
Materials			**2,00**	

There were no significant variations against the plan, and also no special, unforeseen difficulties. The cost of subcontractors was agreed beforehand, so there was no variation. Effort of FU was 3 days more than planned for Task 1, due to the extra documentation work required by the EC. The expenses in materials were overestimated in the planning by 0.5 KEUR. Finally, Task 4 was formally reduced in one week, as the PCBs were available sooner than expected, and one extra week was allowed for testing without altering the project's end date.

10. Subcontractor information

Subcontractor 1
Name: Tedisa
Relevant Expertise & Experience
TECNOLOGIA Y DISEÑO S.A. (TEDISA), is a small electronic engineering company very specialised in PCB an microcontroller design, using last generation CAD systems, robotic projects, data transmission equipment design, software design, etc.
Services provided
Electronic HW design and microprocessor programming

Rationale for choosing / evaluation of the subcontractor

The company has selected TEDISA as subcontractor for the following reasons:

- Experience in microcontroller electronics design
- Willing to co-operate with industry, providing economical and industrial information
- Geographical proximity allowing a smooth technology transfer process

Subcontractor 2

Name: SIDSA

Relevant Expertise & Experience

Broad experience in the management of electronic development projects, both with private and with government or EC funding, having participated as partners or leaders in several Esprit projects

Services provided

Assistance in the technical management of the project

Rationale for choosing / evaluation of the subcontractor

The main reason for choosing SIDSA as management subcontractor was its huge experience managing microelectronics projects within ESPRIT, GAME and FUSE.

Management of the subcontractors:

The first subcontractor was in charge of the design, while the second was assisting the company in the management, the control of the first subcontractor and in the preparation of all the technical documentation. This arrangement, besides the help of the TTN, has proved to be an efficient approach for a company that has to deal for the first time with an electronic-based development project.

Contractual issues:

The contract was closed in price against the specification, and no specific penalties for delays were included, but a clause specifying that a new schedule and price would be negotiated in case the company wanted extra performance not included in the initial spec.

The IPR of the developed product remained the property of Purgasa.

11. Barriers perceived by the company in the first use of the AE technology

There were several barriers that prevented the company from adopting a new technology to improve its products.

Knowledge barriers

The company had to jump over an important gap between its knowledge on just mechanical technology to the electronic one. In this sense, the company did not know at first how to power the intelligent steam traps. Furthermore, the company did not know prior to the AE what were the electronic solutions and how to select the most suitable microelectronic technology options.

Psychological barriers

The company had a genuine fear of any electronic technology, due to its lack of experience and expertise in such technologies. The steam traps designs had just a mechanical content, and the FU had never considered necessary before the AE to implement electronics. Moreover, some attempts from larger manufacturers of incorporating electronics to the valves were not successful.

Technology barriers

The lack of experience and expertise of the company in electronics made it very difficult at first to specify the technical features of the electronic board and the microprocessor. However, the worst technological trouble was the definition and implementation of the energy solution, as the company did not know anything about energy problems and an innovative technique to charge and discharge the batteries that feed both the electronics and the alarm device had to be developed.

Financial barriers

Since the start of the project this was a very important barrier for a small company as Purgasa operating in a market mainly performed by large customers, we want to remind the company has, the most of the cases, to finance its sales during 180 or even more days.

12 . Strategy / steps taken to overcome barriers and arrive at an improved product

Purgasa wanted to carry out the project, although was concerned about the way to do it. In this sense, the FUSE program has helped the company to overcome some barriers in the following aspects:

FUSE has provided not only economic but specially technical backing and independent advice to the project. In the critical task of selecting a suitable subcontractor, the independent advice of the TTN made the company feel more confident that the project would have a 'happy end'.

FUSE, by reviewing and suggesting changes to the AE proposal, and later through the TTN monitoring, has set up a strict control of the project, in respect to its budget, tasks, times and reasoning of deviations. This is very important for a company in their first project, as the real cost of different tasks and the definition of realistic schedules cannot be done by a newcomer alone. The independent advice given by FUSE helped the FU also to see that the risk of failure was under control, thus removing almost all of the psychological barriers.

Concerning the knowledge barriers, they were effectively removed by allocating an engineer from Purgasa almost full time to the project. He was very often at the subcontractors' facilities, learning and collaborating with their staff and transmitting all the necessary steam traps knowledge. Logically, Purgasa had no experience in electronics but also neither TEDISA nor SIDSA had experience in traps (regulations, markets, competitors, functionality); it seemed important to merge them.

The result was a bi-directional flow of information that helped the company to learn what was required achieve the electronic product. Now the FU is confident on its ability to quickly implement any necessary changes required by customers and providing a much better technological image.

13. Knowledge and experience acquired

The First User has gained experience with electronic PCB circuits and microprocessors for controlling of mechanical valves and steam traps.

The First User is now able to specify and designing an autonomous intelligent system using CAD tools and to design and evaluate hardware systems using PCBs and microprocessors.

Being more specific, the following is the list of knowledge that the company has acquired:

- Technical management of electronic based products
- Product specifications of electronic products
- Technology choice
- Subcontractor choice
- Project planing and management
- Design of electronic products
- Learning interaction between software and hardware
- Testing and training electronic products
- Product, economic and competitive analysis

The learning process was mainly developed while conducting the AE. That way of knowledge acquisition was certainly profitable for the company.

14. Lessons learned

Most important lesson learned during this AE was to realise that psychological barriers were stronger than technological ones. We learned that psychological barriers had limited our company for many years. In fact, we knew the problem many years ago but psychological barriers made impossible to look for the appropriate technology to solve the problem.

It has to be taken into account that the company has never used electronic technology before this AE. In fact the company had neither expertise nor experience in electronics technology, so Purgasa was able neither to specify nor to design the IASTS. The purely mechanical background of the company made very difficult to reach the necessary expertise in specific microelectronics development areas such as specification, design, test and tools in order to implement electronics on the existing steam traps.

The key point to succeed in this transfer of electronic knowledge, whilst keeping an efficient usage of the existing technologies, is the combination of suited staff background (academic and professional) with a detailed work plan. We learned that our co-operation with the subcontractor was essential to get a reliable and very well designed product.

We also learned to deal with strong limitations and legal restrictions for designing intrinsically safe electronics, an important issue that may lead to problems if not foreseen from the beginning.

Perhaps one of the most important lessons learned has been that microelectronics is less expensive than initially thought. The measurements should be expressed in terms of cost/effectiveness, which means that even being more expensive than the equivalent mechanical device, it is much more performant.

15. Resulting product, its industrialisation and internal replication

With the prototype working as expected in the field tests, the company now involved in the tasks to industrialise the new bimetallic steam trap provided of the electronic control as soon as possible.

Purgasa is rapidly setting up the industrialisation procedures to manufacture and installing 440 samples of the new steam trap prepared to pass a long term field testing. The samples will be installed in 4 months time.

The total investment required to release the bimetallic steam trap into the market is the combination of the electronic development cost (60 KEUR) and the mechanical changes in the steam trap to adapt the electronic module. These changes amount to 57 KEUR, so total development cost is 117 KEUR. The following chart provides details of the industrialisation costs:

Task/ concept description	Duration/ effort (weeks)	Cost (KEUR)
Instrumentation	2	26
Electronic assembly	18	43
Marketing and training documentation	20	13
TOTAL	*46*	*82*

The total investment to be amortised is 82 + 117 = 199 KEUR.

The first replication within the company using the experience acquired with this AE will be an RF transmitter for transmitting the alarm to the control room.

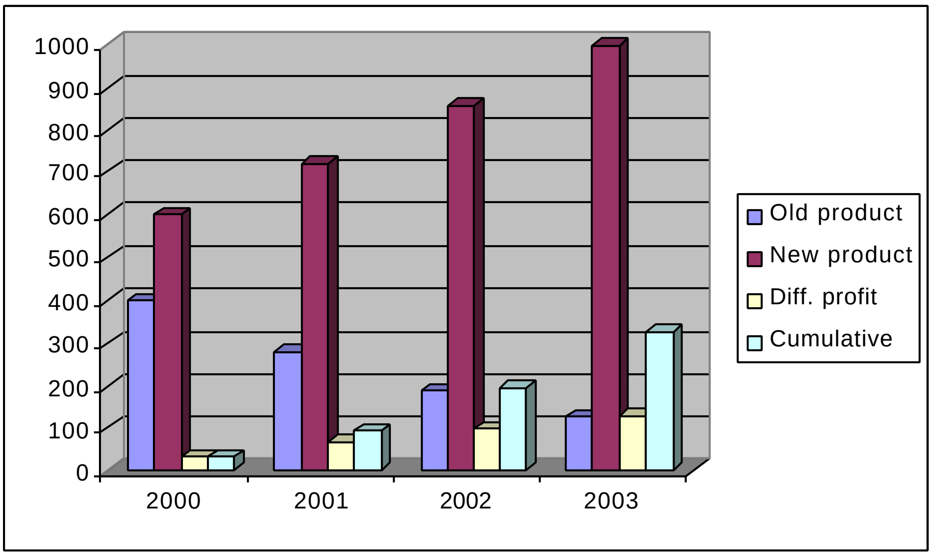
16. Economic impact and improvement in competitive position

Now with the upgrades derived from this Application Experiment, Purgasa has an expectation of increasing its sales between the years 2000 and 2003 in app. an accumulative 56%, (see below histogram), both in Spain and abroad. In fact, by now the company has signed export contracts with distributors in Egypt, Korea, Singapore and Italy, and is negotiating with distributors in South Africa, USA and France. The company has the intention to remain in the bimetallic high end zone. Consequently, the price of Purgasa's product, which will be 20% more expensive than the former product, will offset this weakness by better marketing the product in the segment of large companies, who appreciate in the first place the technical advantages and disadvantages of the product and secondly the price.

The direct economic impact for Purgasa is based on the true possibility of stopping the present declining trend of sales revenues. The key point to economically succeed has to do with the important saving offered to the refineries when using the IASTS. In fact, 7% of classical steam traps lose energy (25 Kg/h average). End users normally make inspections every six months. It means, 7% steam traps are losing 25 Kg/h steam during three months in a period of six months.

Steam costs about 6 Euro/Tm. supposing a small refinery with 5000 classic steam traps installed the energy loss of steam during a year is:
5000 units x 0,07 (%) x 0,025 Tm/h x 8000 h/year x 6 Euro/Tm = 420.000 Euro/year
Maintenance and inspections cost would be 72.000 Euro/year
IASTS will reduce maintenance cost to 20.000 Euro/year and energy loss would be eliminated. Then IASTS will save to the end user 472 KEuro/year, a good reason to invest in our product.

Based on this clear advantage to the end user, it seems very likely to achieve the commercial objectives shown in the next chart. The figure shows the foreseen situation for the years 2000-2003 considering two different hypotheses: a) if the AE was not implemented, so sales would continue its current decline, and b) with the new product, thanks to the advantages offered to



the end user, the sales figure will rise.

The difference in profit can reasonably reach 300 KEUR by 2003, this means that the investment of app. 200 KEUR would be recovered in 3 years and 150% ROI (300 KEUR differential profit / 200 KEUR investment) will be attained after four years of the product in the market.

17. Summary of best practice and target audience

This AE is an example of the big increase in functionality that can be obtained by the application of microcontrollers to an electromechanical product. It provides useful practical information regarding the selection of a suitable microcontroller, and also stresses the importance of designing for battery and solar cell powering and low power consumption.

We believe there are various sets of companies that could be the target of this demonstrator for dissemination purposes:

- Companies in the same or similar field of application, usually small-medium companies, which could be still reluctant or concerned about the chance to succeed in developing a project to migrate from just mechanical bimetallic steam traps to an intelligent device like the IASTS. The dissemination document encompasses useful information also for any kind of SME supplier of the large oil refinery plants.
- Engineering and other companies integrating piping with heat exchanger, drip legs, turbine protection, steam atomiser, etc for refineries. Those medium-large companies keep often a close contact with the innovation occurred at the components' level.
- Maintenance responsible of refineries and steam traps users who usually want to keep updated of the new developments and innovations implemented over the components and subsets they are installing or acquiring.