PROJECT NO: FP6-508402

SAFEVEND

New generation automated fruit juice vending machine
To reduce food poisoning of the children and the working population

Co-operative Research (Craft)

Horizontal Research Activities Involving SMEs

Final Activity Report
Date of issue of this report: May 2006

Start Date: 1st February 2004 Duration: 27 Months

Lead Contractor: Autonumis Ltd.

Version 0.1

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PROJECT INFORMATION

PROJECT NO: FP6-508402

CONTRACT NO: COOP-CT-2003-508402

TITLE OF PROJECT: SAFEVEND - *New generation automated fruit juice vending machine to reduce food poisoning of the children and the working population*

COORDINATOR: Autonumis Ltd

SME EXPLOITATION MANAGER: Autonumis Ltd

***SME CONTRACTORS*:**
Autonumis Ltd
Barcelona Semi-Conductors
SDF Electronics Ltd
Global Cooling BV
Dayla Liquid Packaging Ltd

***OTHER ENTERPRISE / END USER CONTRACTORS*:**
Norpe AS

RTD PERFORMER CONTRACTORS:
Pera Innovation Limited
Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek

EXECUTIVE SUMMARY

This report covers the work carried out in the full duration of the project. The main body of this report is a précised overview. However more detailed appendices are attached to cover the technical work programme.

The proposed CRAFT research project, SAFEVEND, has developed an active controlled vending machine incorporating a novel-mixing chamber that ensures a consistently accurate quality drink is dispensed, while incorporating a sterilisation unit to prevent microbial growth. The cooling or heating energy is supplied by a refrigeration cycle with energy savings on the traditional refrigeration cycle.

Project Management, Co-ordination, Exploitation was on going through the life of the project. All tasks, in all Work Packages, are now complete and good results have been achieved. Technical Reports, on each of these tasks, have been attached to this document.

Regular technical and interim meetings, to discuss technical progress were held every 3 months. Periodic progress and management meetings at months 6, 9, 12, 18 and 27 followed, interspersed with working party meetings. A final meeting was held at the end of the project in month 27. All Meetings were well attended throughout the life of the project, with all partners showing a high level of commitment and enthusiasm.

Achievements:

- The development of patentable technologies for the measurement and metering of the juice.
  - Light absorption measurement chamber, which determines the concentration of the dispensed drink, in real time, by measuring the amount of light transmitted through the liquid at specific wavelengths. Some of the incoming light is absorbed by the liquid, as a result, light of a lower intensity strikes a photodiode
  - A metering and mixing system – using venturi technology to control the mix ratio, in real time, according to data from the light absorption unit.
- Demonstrated to consistently deliver juice at a brix level between 9 and 13 to a tolerance of +/-0.2
- Radio Frequency Identification Technology (RFID) utilised to prevent counterfeiting and tampering with the concentrate, to maintain product quality and brand name confidence.
- Environmentally friendly, fully automated, system sterilization at the point of dispenses.
- An estimated manufacturing cost of €717, less than €1000 outline in the proposal.
- The Safevend system has improved on the original project specification, to reduce power consumed by 25%, and actually achieved a 70% reduction, with the use of alternative Free Piston Stirling Cooler (FPSC) technology. The FPSC unit out performs conventional systems when maintaining the juice at a specific temperature, with improved performance and a fully modulatory nature. During a long-term test, the FPSC unit consumed an average of 13 watts, compared with the Rankine unit that consumed 44 watts, a reduction in power consumed of 70%.

Exploitation/Dissemination Outline:

Initial market stimulation has taken place, contacting leading dispensing machine operators and beverage brand owners. In order to asses their willingness to adopt new technology and to stimulate companies to apply or use the results in their product strategy.

However, with the protection of IPR in mind, the specific details of the Safevend project have not been divulged to any person outside the Safevend consortium. More detailed discussions, with third parties, will take place on completion of patent applications

The protection of the patentable innovations, generated through the Safevend project, is underway and will shortly be concluded. The Safevend production prototype will be launched at the BRAU Beviale trade fair in Nürnberg, 15th-17th of November 2006. BRAU Beviale is one of the most important European trade fairs for the production and marketing of beer and soft drinks.

A secure SAFEVEND web site has been created where the project presentations and documentation can be found.

PUBLISHABLE SUMMARY

Problem:

The number of vending machines in Europe has grown by 20% from 9million in 1997 to an estimated 10million in 2002. They now constitute an integral feature of most work places with more than 80% of the work force drinking out of automated vending system at any one point in the day.

An estimated 120,000 man-days, are lost annually to stomach bugs caused by water borne bacteria growing in the remote parts (not easily cleaned portions) of the vending machine and dispensed through the drinks costing businesses an estimated at €1.2bn pa. Similarly the quality of the drink is not assured because the mixing is subject to operator error in settings or malicious attempt to maximise profit by over diluting the drinks. This leads to lack of protection for the drink brand leading to loss of business.

The Consortium:

The project is particularly relevant to small to medium sized (SME's), which are currently heavily exposed to issues related to globalisation of trade. Most international competitors have virtually identical dispensing technologies to those in Europe and can compete on quality and delivery, and are more competitive in terms of costs. The European SMEs, within the Safevend project, have identified the need to innovate in order to differentiate and add value to what is a low technology market sector.

The project partners, lead by the coordinator Autonumis, are spread throughout four member states. Autonumis, SDF Electronics and DAYLA from the UK; BCN from Spain; Global Cooling based in the Netherlands and NORPE from Norway. The geographic locations of the companies, who make up the consortium, provides this project with an even spread across Europe.

Objectives:

The Societal and policy objectives of this project are to improve the health and quality of life of the adult and children users of vending machines, by promoting quality assured healthy fruit juice drinks. The proposed technology will reduce the risk of food poisoning and protect our environment by reducing the amount of power-consumed.

Achievements:

The consortium has just completed the two-year research and development project. This Safevend project has generated new patentable technologies for the measurement and control of concentration mix ratios of dispensed fruit juice drinks, reconstituted from high quality concentrate.

For the first time, in the dispensing market sector, it is possible to maintain a high quality drinks dispense without operator intervention. Including product authentication, brand control, quality control and fully automated cleaning systems.

The Safevend production prototype will be launched at the BRAU Beviale trade fair in Nürnberg, 15th-17th of November 2006. BRAU Beviale is one of the most important European trade fairs for the production and marketing of beer and soft drinks, with 1,400 exhibitors and 38,000 trade visitors. The annual trade fair ensures a successful mixture of an extensive range of beverage raw materials, technologies, logistics and marketing

For more information, relating to exploitation and dissemination of the technology, please contact:

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For research queries please contact:

Paul Holdsworth at Pera paul.holdswoth@pera.com

SECTION 1 - Summary of Objectives and Achievements

1.1 Overview of General Project Objectives

Scientific Objectives:

The scientific objective of this project was to enhance knowledge of the microbial growth (in an automated dispensing machine) by identifying the pattern of growth and quantifying the level of activity in the fluid that makes it toxic for human consumption. This knowledge was validated and compared with the existing knowledge on microbial activities in drinking water and food (drink) poisoning helped to specify the level and the timing of sterilization activities within the mixing and the delivery nozzles. Similarly, knowledge has been enhanced through the increased understanding of the refractive indices of fluids and the relationship to both the brix level and the change in refractive index with increasing level of microbial activities. While the Stirling engine is gaining increasing popularity in the laboratory and in aerospace applications the use in commercial applications is low. The Safevend project has opened other avenues for this emerging technology.

Technological Objectives:

The technology objective of our work was to provide Europe's automated dispensing industry with an innovative technology capable of competing globally. We provided a cost effective manufacturing method, design technology and an innovative drink dispensing machine to improve the quality of life of European workers and students. The demands are for the ability to accurately and independently verify the quality of the drink while the potential for infecting the drinks is reduced. To achieve these objectives, at the start of the project, the following operational targets were identified:

- Ability to consistently deliver juice at a brix level between 9 and 13 to a tolerance of +/-0.2
- Ability to accommodate up to 10 litre pre-packed juice in a refrigerated cabinet
- The ability to accept different bag-in-box juice from any supplier.
- The implementation of a cooling media with a cooling capacity of 100W at O°C (cold end)/30°C warm end, operating at COP of 1.3-1.4 at the ASHRAE condition of -23.3°C/54.4°C.
- Ability to chill up to four 15-litre compartments to a temperature of less than 4ºC capable of small footprint of less than 500mm X 500mm for a 2-flavour juice dispenser.
- Capable of environmentally friendly drink sterilization at the point of dispense i.e. in the mixing chamber and the dispense nozzles where the sugary left over of the drinks enhance microbial growth.
- A manufacturing cost of less than €1000 for a 2-flavour juice dispense
- Reduce power consumption of a typical dispensing machine by 25%.

Societal & Policy Objectives:

The Societal and policy objectives of this project are to improve the health and quality of life of the adult and children users of vending machines. The developed technology will reduce the risk of food poisoning and protect our environment by reducing the amount of power consumed. Based on the projected market penetration of 1%, we specifically aim to:

- Reduce current estimated food (including drink) poisonings by 90000 per annum.
- Reduce the number of days lost to stomach bugs by 108000 days
- Reduce CO_2 emissions by 25000Kg per annum
- Improve social cohesion by reducing the variations in severity of the effect of water borne poisoning across the Union with respect to vended drinks especially in Finland, Netherlands and Slovenia.
- Contribute to the implementation of European Community Council Directive No 80/778/EEC. By ensuring that the bacterial colony count levels already established for the quality of water intended for human consumption in vending machines does not multiply in the machine by the favourable condition (for multiplication) provided by the presence of the sugary drink.
- Improve and contribute to the requirement of Council Directive 93/43/EEC on the hygiene of foodstuffs, which requires foods (and drinks) that are likely to support growth of pathogenic micro-organisms or the formation of toxins to be kept, at all times, at temperatures which would not result in a risk to health. The proposed technology will contribute to the effectiveness of this directive by ensuring the sterilization of other parts of the machine that may not be kept cold indefinitely.

Economic Objectives to Improve Competitiveness:

The *Economic Objective* of this project is to give Europe a significant lead in the international market place, especially against USA and Japanese companies that are currently actively involved in developing power conscious and intelligent automated vending systems. The health and consistent quality assurance functionality should enable a 1% market penetration of the current market within 5 years after the RTD. A total of 6500 jobs opportunities will be created and safeguarded across the union by the estimated sales as shown below:

- Domestic and displaced imports of automated vending and dispensing machines of €500M p.a. safeguarding 3300 jobs.
- Exports of vending/dispensing machines into the global market of €305M p.a. thereby creating 2000 jobs.
- New growth in the automated vending of fruit juice in €19.4M p.a. creating 130 new jobs
- New sales (growth) of compact cooling system of €160 M p.a., creating 1060 jobs
- New sales (growth) of brix control unit of €2M p.a. creating 13 jobs

In addition, it is expected that a 1% market penetration will result in 25% reduction in the energy required for running these machines resulting in savings of €1Bn in cost of operation across the Union while reducing production time loss and absenteeism in schools by an estimated 108000 man days.

Enabling Innovation-Related Objectives:

In order to achieve the societal and economic objectives that come from the dissemination and exploitation of the research results, we have defined an enabling set of Innovation-related objectives as follows:

- To formulate the project results into a protectable form and apply for patent protection on the brix control unit and inline-integrated mixer. This process is currently underway.
- To transfer knowledge from the RTD performers to the SME participants through 3 exhibitions per annum, to facilitate technology transfer between potential users.
- To broadcast the benefits of the developed brix control, sterilisation and alternative compact cooling technology and knowledge beyond the consortium to potential industrial user communities such as food and drink processing industry, domestic and industrial refrigeration and cooling industries.

Specific activities:

- We will contact an expected 1000 firms through the memberships of Automatic Vending Association, European Vending Association, and National Automatic Vending Merchandising Association (USA)
- Three exhibitions relating to the relevant aspects of the technology will be attended per annum with potentially two workshops in conjunction with the exhibition or independently. The exhibitions in which the product is expected to include Eurovend, AVEX (UK) and BDV (Germany).
- An estimated 20 companies will be stimulated to adopt the technology through the different network of associations and business affiliations between the consortium members and Eurexel.
- Six companies will be targeted for licensing mainly from the companies above.
- A specific dissemination workshop will be held in an accession country (probably Poland) to broadcast and promote the benefits of the technology to accession companies and organisations.

1.2 Summary of Recommendations from Previous Reviews

The commissions undertook the formal review, dated 05/07/05, of the Month 12 report. The results were extremely favourable, a summary of the comments and recommendations are below:

Comments:
"The project is continuing to plan. Partner attendance is reported to be good at all of the scheduled meetings. Consortium is cooperating well and controlled by the technical board. Clear dissemination and exploitation plans are under development and leaded by a dedicated exploitation manager."

"Good to excellent project (The project has fully achieved its objectives and technical goals for the period and has even exceeded expectations)."

Recommendations:
The project is progressing well is expected to achieve the final results in accordance with the DOW plan. No recommendations are made at this stage. However, in future it is important that deadlines are met for the submission of the report as specified in the contract. Alternatively if the deadlines ca not be met it is important that Commission services receive early notice of the delay."

1.3 Summary of Objectives & Major Achievements for Project

The specific objectives for the project are summarised in the table below.

Del No.	Deliverable Name	WP No.	Lead Participant	Estimated Person Months	Nature	Dissemination Level	Del. Date	Progress Towards Achieving Objectives	% Complete
D1	Research test rig	1.1	DAYLA	11.6	P	CO	2	Test rig designed and manufactured.	100
D2	Microbial contamination	1.4	DAYLA	11.6	R	CO	2	- Hygiene Tests conducted on fruit juices. - Concept hygiene mechanisms generated. - Cleaning and disinfection outlines established in line with European legislation.	100
D3	Model of Brix control mix	1.2	DAYLA	11.6	R	CO	4	- Performance curves for fruit juices generated. - Temperature calibration curves defined.	100
D4	FPSC development and tests	3.1	GLOBAL COOLING	16.7	P, R	CO	5	- Ambient rig designed and manufactured. - Baseline test data generated. - Integration of FPSC unit and control electronics.	100
D5	Index mapping to drinks quality	1.3	DAYLA	11.6	R	CO	6	- Brix tables established for fruit juices reconstituted from concentrate. - Refractive Index versus Brix tables generated.	100

Del No.	Deliverable Name	WP No.	Lead Participant	Estimated Person Months	Nature	Dissemination Level	Del. Date	Progress Towards Achieving Objectives	% Complete
D6	Heating and cooling	3.2	GLOBAL COOLING	16.7	R	CO	7	- Test rig designed and built to transfer cold energy from the FPSC unit to cabinet - Test rig designed and built for cold energy storage - Test data tables produced	100
D7	Adaptive control energy monitoring	3.4	GLOBAL COOLING	16.7	P, O	CO	7	- Temperature control and monitoring electronics incorporated within the cooling system - Tests performed to establish FPSC performance - Circuit layout for the complete system control designed	100
D8	Refractometer and control development	2.1	BCN	9.6	P	CO	8	- Light absorption identified as alternative technology to refractometry. - Light measurement chamber designed and developed. - Mix control chamber developed through four design iterations	100
D9	Steam generation unit design	3.3	GLOBAL COOLING	16.7	P, R	CO	9	- Design of steam generation unit complete	100
D10	Brix measurement and sensor control algorithm	2.2	BCN	9.6	O	CO	10	- Light absorption measurement inputs taken - Data analysed and relative Brix measurements identified for subsequent use with the mix control valve	100

Del No.	Deliverable Name	WP No.	Lead Participant	Estimated Person Months	Nature	Dissemination Level	Del. Date	Progress Towards Achieving Objectives	% Complete
D11	Steam sterilisation modelling	4.1	SDF	9.0	R	CO	11	- Development of mathematical model complete - Calculations performed	100
D12	Hardware Implementation and tests	2.3	BCN	9.6	R	CO	12	- Proportional, Integral, Derivative algorithms used to control the mix valve - Signal conditioning performed on output from the light absorption chamber and output from the PID controller - Tables produced showing the performance of the measurement chamber and control valves	100
D13	Hardware Implementation and tests	4.2	SDF	9.0	P, R	CO	13	- Steam sterilisation rig produced on 3D CAD - Customised rig constructed - In-line testing protocol completed - Testing completed - Ozone sterilisation investigated	100
D14	Electronic Hardware & Software	4.3	SDF	9.0	O, R	CO	15	- In-line cleaning regime established - Recommendations made	100
D15	Hardware Integration & Build	5.1	AUTONUMIS	21.4	R	CO	18	- The primary sub-systems modelled on 3D computer aided design system (CAD) - One final dispense system has been designed and assembled using 3D CAD - Parts breakdown - Subsystem prototype manufacture complete	100
D16	Integrated Prototype Assembly	5.2	AUTONUMIS	21.4	P, R	CO	20	- Subsystems testing complete	100

Del No.	Deliverable Name	WP No.	Lead Participant	Estimated Person Months	Nature	Dissemination Level	Del. Date	Progress Towards Achieving Objectives	% Complete
D17	Closed Loop Control Integration	5.3	AUTONUMIS	21.4	P	CO	23	- Separate subsystem control electronics developed - Control algorithms developed for microprocessor	100
D18	Test and Technical Validation	5.4	AUTONUMIS	21.4	R	CO	27	- Brix dispense repeatability established - Temp dispense performance restrictions identified - Cleaning performance proved - Water bath tested - Cooling subsystem tested and refined	100
D19	Protection of IPR	6.1	AUTONUMIS	10.8	R	CO	27	- Novel innovations identified - Possible competitive patents researched and assessed for possible conflicts - Patent agent selected - Provisional meeting with patent agent held - Final project innovations selected and patent agent instructed to draft specification	100
D20	Absorption of results by proposers	6.2	NORPE	10.8	R	CO	27	- Final project report produced - All demo units passed to partners - Full system documentation and specification supplied to partners	100
D21	Dissemination of knowledge	6.3	NORPE	10.8	R, O	PU	27	- Initial disclosure restricted to protect IPR - Prototype to be presented at BRAU Beviale trade fair in Nürnberg,	100

Del No.	Deliverable Name	WP No.	Lead Participant	Estimated Person Months	Nature	Dissemination Level	Del. Date	Progress Towards Achieving Objectives	% Complete
D22	Socio-economic aspects	6.4	NORPE	10.8	R	PU	27	- System spec drafted, including standards that the system will comply with - EHEDG design outlines followed	100
D23	Promotion of exploitation	6.5	NORPE	10.8	O	PU	27	- Companies contacted for market research/stimulation	100
D24	Coordination of knowledge and IRA	7.1	AUTONUMIS	17.2	R	CO	27	- Technology implementation plan has and the production specification unit specification drafted	100
D25	Co-ordination of the technical	7.2	AUTONUMIS	17.2	R	CO	27	- Co-ordination of EC requirements for communication and reporting	100
D26	Co-ordination of legal aspects	7.3	AUTONUMIS	17.2	O	CO	27	- Provision of bank guarantees and audit certificates	100
D27	Coordination of other issues	7.4	AUTONUMIS	17.2	R	CO	27	- The ethical relevance of the project is not applicable, as the research does not involve any testing on animals, humans, plants or any other living species	100

1.4 Issues During the Project

During the initial stages of task 2.1, Refractometer and Control Development, measurement technology focus was redefined.

Using the test results form task 1.2 and through discussions with BCN it became evident that refractometry, used to monitor and control the juice quality, wasn't the most appropriate technology. Light absorption was suggested, as alternative, which could perform the same functions as the refractometer but using fewer components and at a fraction of the cost. This concept was introduced to the consortium at the month-6 meeting.

Following an initial agreement to evaluate the new technology, a simple test chamber was developed to assess the feasibility and repeatability of light absorption. These tests proved the technology and were extremely encouraging and were presented at the month 9 meeting. The technology has since been developed into a patentable system. The patent process, for the measurement chamber and mixing head are currently underway.

Through development and assessment of the 40W FPSC technology the consortium felt that, despite demonstrated efficiency over conventional Rankine compressors, it did struggle to bring product down to temperature. This problem was discussed at the month 15 meeting 26/05/05, where an alternative technology was discussed, the Electronic Expansion Valve (EEV). The EEV is a retro fir component added to a conventional Rankine compressor system and will vastly improve the efficiency of the unit.

SECTION 2 - Work Package Progress Review

2.1 Work Package Objectives

The specific work package objectives for the full duration of the project are summarised in the table below.

Work Package No.	Work Package Title	Lead Contractor Short Name	Person Months	Start Month	End Month
1.1	Test Rig Development	Dayla	3.3	1	2
1.2	Model of Brix Control Mix	Dayla	2.7	3	4
1.3	Index Mapping to Drinks Quality	Dayla	2.9	5	6
1.4	Microbial Contamination	Dayla	2.7	1	2
2.1	Inline Refractometer Development	BCN	3.4	7	8
2.2	Brix Measurement Algorithm	BCN	2.8	9	10
2.3	Hardware Implementation and Tests	BCN	3.4	11	12
3.1	Stirling Cooler Development	Global Cooling	4	3	5
3.2	Heating & Cooling Energy Transfer	Global Cooling	4.6	5	7
3.3	Steam Generation Unit Design	Global Cooling	3.1	7	9
3.4	Adaptive Control Energy Monitoring	Global Cooling	5	5	7
4.1	Steam Sterilization Modelling	SDF	2.8	10	11
4.2	Hardware Implementation and Tests	SDF	3.2	12	13
7.1	Coordination of knowledge and IRA	Autonumis	10.4	1	27
7.2	Co-ordination of the technical activities	Autonumis	3.6	1	27
7.3	Co-ordination of legal aspects	Autonumis	1.6	1	27
7.4	Coordination of other issues	Autonumis	1.6	1	27

2.2 Deviation from the Plan and Corrective Actions

Work Package No.	Title	Deviations from Plan	Corrective Action
2.1	Refractometer and Control Development	Alternative technology identified by partner - BCN	Alternative technology researched, developed, tested and proved to be superior for this application
4.2	Ozone generator	Complimentary cleaning technology identified by partner – Autonumis	Alternative technology researched
4.2	Hardware Implementation and tests	Existing test rig circuits are oversized, have a large water flow and operate at higher pressures than vending machine conditions (1,5 bar).	- Extra capacity (man-hours) was brought into the project. - A Customised test rig is constructed. - Mid period review of the test rig. - Integrated test rig > 09/05 - Preliminary tests and evaluation > 10/05 - Mid period review with task group -> 10/05
4.3	Electronic Hardware and Software Development	Impact from task 4.2 delay.	- Mid period review with task group > 10/05 - Modification to test rig, control algorithms, analysis > 11/05. - Steam cleaning regime. > 11/05 / Month 21 meeting. - Project extension of 3 months requested and granted
5.4	Test and Technical validation	Through development and assessment of the 40W FPSC technology the consortium felt that, despite demonstrated efficiency, it did struggle to bring product down to temperature.	Integration and testing of additional alternative technology, the EEV valve, supplied by Global Cooling. As discussed at the month 15 meeting 26/05/05
6.3	Dissemination of Knowledge	Consortium agreed that Safevend should not be publicly disclosed as this could be counted as prior publication of the inventions and could prevent a patent from being granted.	Once the patent application has been filed the production prototype will be presented at BRAU Beviale trade fair in Nürnberg, 15th-17th of November.

2.3 Work Package Deliverables Update

Del. No.	Deliverable Name	WP No.	Lead Participant	Date Due	Delivery Date	% Complete
D1	Research test rig	1.1	Dayla	2	2	100
D2	Microbial contamination	1.4	Dayla	2	2	100
D3	Model of Brix control mix	1.2	Dayla	4	4	100
D4	FPSC development and tests	3.1	Global	5	5	100
D5	Index mapping to drinks quality	1.3	Dayla	6	6	100
D6	Heating and cooling	3.2	Global	7	7	100
D7	Adaptive control energy monitoring	3.4	Global	7	7	100
D8	Refractometer and control dev.	2.1	BCN	8	8	100
D9	Steam generation unit design	3.3	Global	9	9	100
D10	Brix measurement and sensor control	2.2	BCN	10	10	100
D11	Steam sterilisation modelling	4.1	SDF	11	11	100
D12	Hardware Implementation and tests	2.3	BCN	12	12	100
D13	Hardware Implementation and tests	4.2	SDF	13	13	100
D14	Electronic Hardware & Software	4.3	SDF	15	15	100
D15	Hardware Integration & Build	5.1	Autonumis	18	18	100
D16	Integrated Prototype Assembly	5.2	Autonumis	20	20	100
D17	Closed Loop Control Integration	5.3	Autonumis	23	23	100
D18	Test and Technical Validation	5.4	Autonumis	24	27	100
D19	Protection of IPR	6.1	Autonumis	24	27	100
D20	Absorption of results by proposers	6.2	Norpe	24	27	100
D21	Dissemination of knowledge	6.3	Norpe	24	27	100

Del. No.	Deliverable Name	WP No.	Lead Participant	Date Due	Delivery Date	% Complete
D22	Socio-economic aspects	6.4	Norpe	24	27	100
D23	Promotion of exploitation	6.5	Norpe	24	27	100
D24	Coordination of knowledge and IRA	7.1	Autonumis	24	27	100
D25	Co-ordination of the technical	7.2	Autonumis	24	27	100
D26	Co-ordination of legal aspects	7.3	Autonumis	24	27	100
D27	Coordination of other issues	7.4	Autonumis	24	27	100

2.4 Work Package Milestones Update

Milestone No.	Milestone Title	Completion Date	Update	Verification Level
M1	Process Science	Month 6	100% Complete	R, CO
M2	Brix Control Unit	Month 12	100% Complete	R, P, CO
M3	Energy Optimisation	Month 9	100% Complete	R, P, CO
M4	Hygiene Assurance	Month 15	100% Complete	CO
M5	Prototype Integration	Month 27	100% Complete	CO
M6	Innovation Related Activities	Month 27	100% Complete	CO, PU
M7	Consortium Management	Month 12, 27	100% Complete	CO

SECTION 3 - Consortium Management

3.1 Consortium Status

No changes have been made to the consortium. The project has progressed extremely well with very constructive technical and commercial discussions at the meetings, as described in the minutes, with regular communication taking place between the Partners. In addition to the formal meetings a number of working party meetings have occurred to discuss the technical aspects of the project.

Unfortunately TNO, one of the RTD performers, was forced to make significant redundancies, which adversely affected the project. TNOs prime contact and project manager for the Safevend project, Mr Ab Van Zanten, was unfortunately one of those made redundant. Subsequently the work programme was affected, outside the consortiums control, this led to an unforeseen delay in certain tasks. A new project manager from TNO, Mr Karl Sewalt, was assigned to the project. However the work programme was delayed by three months.

To compensate for this delay the consortium requested an extension of 3 months, which was agreed and minuted at the month 18 meeting. This extension was granted by the EC and enabled the delayed tasks to be completed, this extension allowed the project to continue successfully.

3.2 Work Programme

No.	TASK	PARTNERS	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
WP1	PROCESS SCIENCE	5																											
1.1	Test Rig Development	1,2,3,5,7	—	—																									
1.2	Model of Brix Control Mix	2,5,7			—	—																							
1.3	Index Mapping to Drinks Quality	1,2,3,5,7					—	—																					
1.4	Microbial Contamination	1,5,8	—	—																									
WP2	BRIX CONTROL UNIT	2																											
2.1	Inline Refractometer	1,2,3,5,7							—	—																			
2.2	Brix Measurement Algorithm	1,2,3,5,7									—	—																	
2.3	Hardware Implementation and	1,2,3,5,7											—	—															
WP3	ENERGY OPTIMISATION	4																											
3.1	Stirling Cooler Development	1,2,4,6,7			—	—	—																						
3.2	Heating & Cooling Energy	1,2,4,6,7					—	—	—																				
3.3	Steam Generation Unit Design	1.2.4.8								—	—																		
3.4	Adaptive Control Energy	1,2,4,7					—	—	—																				
WP4	HYGIENE ASSURANCE	3																											
4.1	Steam Sterilization Modelling	1,3,8										—	—	—	—	—	—	—	—	—	—	—	—						
4.2	Hardware Implementation Tests	1,2,3,8												—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4.3	Electronic Hardware & Software	1,2,3,8														—	—	—	—	—	—	—	—	—	—	—	—	—	—
WP5	PROTOTYPE INTEGRATION	1																											
5.1	Hardware Integration & Build	1,2,3,4,5,6,7,8																—	—	—									
5.2	Integrated Prototype Assembly	1,2,3,4,5,6,7,8																		—	—	—	—	—	—				
5.3	Closed Loop Control Integration	1,2,3,7,8																								—	—	—	
5.4	Test and Technical Validation	1,2,3,4,5,6,7,8																										—	—
WP6	INNOVATION RELATED	6																											
6.1	Protection of IPR	1,2,3,4,5,6,7,8													—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6.2	Absorption of results proposers	1,2,3,4,5,6,7,8																						—	—	—	—	—	—
6.3	Dissemination of knowledge	1,2,3,4,5,6,7,8																										—	—
6.4	Socio-economic aspects	1,2,3,4,5,6,7,8																										—	—
6.5	Promotion of exploitation	1,2,3,4,5,6,7,8																											
WP7	CONSORTIUM MANAGEMENT	1																											
7.1	Coordination of knowledge /IRA	1,2,3,4,5,6,7,8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7.2	Co-ordination of technical	1,2,3,4,5,6,7,8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7.3	Co-ordination of legal aspects	1,2,3,4,5,6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7.4	Coordination of other issues	1,2,3,4,5,6,7,8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Project Meetings		X		X			X			X			X			X			X			X			X			X
	Milestones							M						M						M									M

3.2 Clarification of Changes to Work Programme

During the initial stages of task 2.1, Refractometer and Control Development, measurement technology focus was redefined. Through discussions with BCN it became evident that refractometry, used to monitor and control the juice quality, wasn't the most appropriate technology. Light absorption was suggested, as alternative, which could perform the same functions as the refractometer but using fewer components and at a fraction of the cost. This concept was introduced to the consortium at the month-6 meeting.

Following an initial agreement to evaluate the new technology, a simple test chamber was developed to assess the feasibility and repeatability of light absorption. These tests proved the technology and was presented and agreed at the month 9 meeting.

3.4 Meetings & Communication

There have been ten project review meetings since the start of the project. These have all combined technical, management and exploitation issues.

Project Review Meetings

	Date	Type of meeting	Location
1	10/03/04	Kick Off	Autonumis
2	19/05/04	Month 3	Pera
3	08/09/04	Month 6	Autonumis
4	25/11/04	Month 9	Pera
5	02/03/05	Month 12	Autonumis
6	26/05/05	Month 15	Global
7	06/09/05	Month 18	Dayla
8	23/11/05	Month 21	BCN
9	01/03/06	Month 24	Autonumis
10	31/05/06	Month 27/Final report meeting	Autonumis

Very constructive technical and commercial discussions have occurred at the project meetings, as described in the minutes and regular communication has taken place between the partners. The partners worked very well together during the project and continue to do so. In addition to the formal meetings a number of working party meetings have occurred to discuss the technical aspects of the project.

Project Work Party Meetings

	Date	Purpose	Location
1	23/02/04	Technology and specification outline	Dayla
2	20/03/04	System Specification	Autonumis
3	29/03/04	Marketing	Norpe
4	30/03/04	System specification	TNO
5	26/04/04	IPR	Autonumis
6	05/05/04	Brix measurement system	Dayla
7	22/06/04	Alternative measurement system	BCN
8	23/06/04	Specification	Autonumis
9	08/07/04	Microbial Contamination	TNO
10	26/08/04	Market research	Autonumis
11	12/10/04	Cooling System	Pera
12	01/02/05	Closed loop control	SDF
13	23/02/05	Market research	Pera
14	12/04/05	Box identification – EMID	Autonumis
15	20/04/05	Prototype integration	SDF
16	06/05/05	Prototype integration testing	SDF
17	10/05/05	Measurement chamber integration outline	BCN
18	17/05/05	RFID Evaluation	Autonumis
19	18/05/05	Measurement chamber integration detail	BCN
20	18/05/05	Barcode Evaluation	
21	19/05/05	Trade show (19/05/05-25/05/05)	USA
22	21/05/05	RFID Supplier – Colder Products	USA
23	25/08/05	IPR	IPR Agent
24	16/09/05	RFID Supplier	Autonumis
25	09/11/05	Mid Period Review of Cleaning Test Rig	TNO
26	14/11/05	Closed loop control	SDF
27	08/12/05	Absorption chamber evaluation	BCN
28	05/01/06	Dayla review of juice dispense system	Pera
29	01/02/06	Closed loop control	SDF
30	27/02/06	Dayla review of juice dispense system	Pera
31	13/03/06	Closed loop and calibration control	SDF
32	16/03/06	Autonumis project/FP6 review	Pera
33	22/03/06	Absorption tech. discussion/dissemination	BCN
34	04/04/06	Safevend FP6 review	Brussels
35	27/04/06	RFID software interface review	Dayla
36	17/05/06	Autonumis review and final report update	SDF
37	22/05/06	Technology/final report update	SDF
38	25/05/06	Technology/final report update	SDF

A website has been created which is an on-line administrative tool for the partners. The administrative element of the website is password protected

3.5 Dissemination Activities

Plan for Use and Dissemination of Project Results – Outline

A dissemination/IPR meeting has taken place to evaluate the systems being developed and their value within the dispensing market. It has been suggested that the systems being developed are commercially extremely sensitive and that it would be detrimental to disclose these developments until the consortium are ready to launch a product. To this end the specific developments and the project itself will, as yet, will not be released into the public domain. Limited marketing has taken place with possible third parties through Norpe and Autonumis, whilst still maintaining the confidentiality of the project innovations.

On filing of a patent(s) the technology will be available for best practice demonstration through the use of case study demonstrations at partner sites, CD ROM design guides and demonstrator videos. Links will be established and the results of the project work disseminated through the memberships of Automatic Vending Association, European Vending Association, National Automatic Vending Merchandising Association (USA) and regulatory bodies will be used to network out the results and help demonstrate the technology to end-users.

The partners will place editorials and technical articles in relevant industry journals, such as The Environmental Technology, Vending Times, The Kitchen, Environmental Products, Industrial Environmental Management, Food Processing and Cleaning Matters. Emerging Internet services such as PJ Online would also be used to promote the technology. These activities are anticipated to commence with the launch of the production prototype at the BRAU Beviale trade fair in Nürnberg, 15th-17th of November, with 1,400 exhibitors and 38,000 trade visitors. The annual trade fair ensures a successful mixture of an extensive range of beverage raw materials, technologies, logistics and marketing

Exploitation & Dissemination Activities Undertaken

Exploitation was discussed at each of the project and working party meetings. The project web page was established in May 2004 including a summary of the project for the public and a section with reports and minutes only for project partners (http://www.pera.com/rndprojects/). Market and patent information has been collected

Protection and Licensing of Knowledge (IPR)

Extensive research has been undertaken into existing patents, that could predate the Safevend innovations, to date no such evidence has been found. The coordinator has interviewed a number of patent agents with a view to protecting the IPR generated within the project. An agent has been selected; the relevant patentable technologies have been discussed with the agent.

An outline of the possible patentable aspect of the system, the mixing head, measurement chamber and motor control, has been drafted as a starting point for the patent agent. Who has now been instructed to draft a legal document called a 'specification', the contents of which will determine whether a patent can be granted.

Dissemination Method

As has been mentioned the systems being developed are commercially extremely sensitive and that it would be detrimental to disclose these developments until the consortium are ready to launch a product. To this end the specific developments and the project itself will, as yet, not be released into the public domain.

Management of Knowledge and IPR

The partnership has already developed an Exploitation Strategy for the management of knowledge, intellectual property and of it's inter-relation with the various innovation-related activities planned. The main innovations in the project will be protected by means of patents or other methods. When the innovations are protected the new scientific knowledge created by the project will be actively disseminated amongst academic communities to validate it, once the patents have been lodged. Hence, the full range of scientific, technological and product/process/system specific dissemination activities can be enabled without compromising the protection of the foreground IPR.

This Exploitation Strategy is being developed into an Exploitation Plan by the first project milestone. The agreement covers the dissemination and exploitation of all the project results to companies outside of the consortium. The agreement also covers collaboration between the partners to fully facilitate exploitation of the foreground technology. This will encompass agreements in respect of the patent application made during the second year of the project, and go on to detail the terms and conditions under which licensing of the technology can take place. This licensing to third parties is seen as critical to the rapid roll out of the technology across the Union and beyond, speeding the proliferation of the technology and penetration of markets sectorally or geographically distant from the partners.

Autonumis have agreed to take the role of dedicated Exploitation Manager within the Project Management Team. Graham Keen has the relevant commercial skills and IPR experience as well as the leadership and business skills to prepare and negotiate the Exploitation Agreement, ensuring that the exploitable results do not cause conflicts of interest amongst the partnership. A key role of the Exploitation Manager is to undertake such steps that are considered necessary to adequately and effectively protect the Knowledge (IPR) that is capable of industrial and commercial application. The costs of such steps will be borne by the Exploitation Manager, unless agreed otherwise. The role will also requires chairing of the Exploitation Board and facilitation of the development and writing of an outline business/exploitation plan and a Dissemination and Use Plan (DUP), based on the results obtained from the Project. Specific technological areas are already being considered for patents. These are the light absorption concentration measurement system and the novel mixing/metering head.

Routes to Exploitation

In preparation for exploitation, the proposers have formed an exploitation committee, lead by the project co-ordinator, AUTONUMIS (partner 1) assisted by end user NORPE (partner 6) because of their understanding of the market, the regulatory bodies and the existing client base. They have created a structured marketing plan, continue to analyse and validate the market potential and structure the segments for case study approach and marketing activity introduce the technology. The proposers will promote this technology through Vending organisations across Europe using the extensive distribution network created by NORPE over the years.

A patent process applied for by Autonumis (partner 1) will protect the outline concept. To achieve this we will establish partnerships, through licenses, with international players in each of the target market sectors, who have the financial capability to globally defend any patent transgression. We intend to create strategic partnership in the Scandinavian, South Europe and Central (or Western) European countries.

Assimilation and Exploitation of the results by the SME proposers

Each Partner will be involved in a continuous process of technology transfer and absorption through their role in the RTD. Appropriate companies will have an input in their areas of specialisation and knowledge would be continuously disseminated at project meetings. The partners would particularly be actively involved in the joint development of the case study and application task. The case study will enable technology transfer to our staff in the operational principles of the developed technology.

The completed technology will finally be absorbed by the partners through a structured programme of technology transfer events using the technology demonstrator system which will typically take the form of workshops and one week (35 working hours) of staff transfer, to work alongside the research staff in the later stages of technology proving and demonstration. An operational guide and good practices guide will be developed jointly with the RTD partners. This is important in enabling the partners to start to plan the implementation of the technology prior to the end of the proposed RTD.

Protection and Licensing of Knowledge

The main innovations in the project will be protected by means of patents. By the second year after project completion it is expected that the technology will be licensed, through the SME Co-ordinator who is currently active in the market, to other service providers across the European Union, to satisfy the demand from industry.

An Exploitation Agreement between the partners has been agreed. The objective of this Exploitation Agreement is to set a framework by which all the project participants can contribute to the achievement of the exploitation and commercialisation requirements of the contract with the EC.

The exploitation agreement between partners also encompass's agreements in respect to the patent application and go on to detail the terms and conditions under which licensing of the technology can take place. The licensing to third parties is seen as critical to the rapid roll out of the technology across the Union and beyond, speeding the proliferation of the technology and penetration of markets sectorally or geographically distant from the partners.

Validation of the Technology

The technology will be validated through laboratory and friendly service providers coordinated by NORPE and the project Coordinator AUTONUMIS who have conducted previous validation tests on these type of systems. Data gathered from the validation tests will be used as a vehicle to promote the technology in post project phases for other specific product applications.

Dissemination Method

In light of the patentable aspects of the Safevend system it has been agreed, by the consortium, that at this stage Safevend should not be publicly disclosed as this could be counted as prior publication of the inventions. Any type of disclosure (whether by word of mouth, demonstration, advertisement or article in a journal), by the consortium, could prevent a patent from being granted. It could also lead to a patent being patent revoked if one was obtained. It is essential that, at this time, Safevend is only disclosed under conditions of strict confidence.

All partners will play an active role in technology transfer and dissemination, once the IPR is protected. The technology will be available for best practice demonstration through the use of case study demonstrations at partner sites, CD ROM design guides and demonstrator videos. Links will be established and the results of the project work disseminated through the memberships of Automatic Vending Association, European Vending Association, National Automatic Vending Merchandising Association (USA) and regulatory bodies will be used to network out the results and help demonstrate the technology to end-users.

Pera, one of the RTD performers will also present consortium-approved papers on the technology, once the IPR has been protected, at suitable conferences and seminars. The technology will also be outlined to visitors as part of a structured presentation of a wide range of leading edge process technologies. Pera receives in excess of 1500 industrial visitors from SME processors and end users. This would provide an ideal means of disseminating the technology and widening uptake.

The partners will place editorials and technical articles in relevant industry journals, such as The Environmental Technology, Vending Times, The Kitchen, Environmental Products, Industrial Environmental Management, Food Processing and Cleaning Matters. Emerging Internet services such as PJ Online would also be used to promote the technology. Once the IPR has been protected these activities will commence with the BRAU Beviale trade fair in Nürnberg, 15th-17th of November, to at least 12 months after the end of the project.

One of the dissemination events will be particularly aimed at accession countries. We therefore will hold a dissemination workshop in an accession country (probably Poland) where the publishable results of the project will be discussed with accession country companies and organisations.

Raising Public Participation and Awareness

As we roll out the technology to other sectors and territories inside and outside of the Union, the partners will be required to undertake technology transfer programmes, through 3 exhibitions per annum to facilitate technology transfer between potential users and licensees in their domestic market. These third party firms will initially be recruited from areas of the Union and accession countries, which we cannot service directly from Norway, Netherlands, Spain or the UK. Hence, significant levels of pan-European technology transfer will take place as the technology proliferates.

The partners will place editorials and technical articles in relevant industry journals, such as The Environmental Technology, Vending Times, The Kitchen, Environmental Products, Industrial Environmental Management, Food Processing and Cleaning Matters. Emerging Internet services such as PJ Online would also be used to promote the technology. These activities will commence on completion of the patent process. The project partners will carry out measurement of the achievement of technology transfer and dissemination targets by logging activities for 2 years after the end of the project

Exploitation & Dissemination Activities Undertaken

A dissemination/IPR meeting has taken place to evaluate the systems being developed and their value within the dispensing market. It has been suggested that the systems being developed are commercially extremely sensitive and that it would be detrimental to disclose these developments until the consortium are ready to launch a product. To this end the specific developments and the project itself will, as yet, not be released into the public domain.

Exploitation & Dissemination Activities Planned

Meetings have been held to discuss machine specification (see annex 2), IPR and dissemination issues. In an attempt to establish the market requirements, which will in turn determine the machine operating parameters, a draft market research document has been compiled. In addition to the research document a number of buyers/users have been targeted. Pera will contact the buyers/users to establish their wants, needs and requirements. During this initial contact the specifics of the Safevend project has not been made known. Following patent applications Autonumis will contact a number of buyers/users for more a more in-depth research.

SECTION 4 - OTHER INFORMATION

4.1 Conclusion

The project has progressed extremely well and developed a number of novel technologies, which will open up new market opportunities, for the consortium, and provide tangible social benefits. The consortium has worked together, steering the research partners, providing guidance, assistance and the specialist knowledge needed for a successful project.

The formal start date for the project was the 1st February 2004. The Kick Off meeting followed on the 10th March 2004. The project started one month late, because of the time needed to arrange a suitable date, which was convenient for all the project partners. This resulted in the initial task delivery dates being slightly behind schedule.

Every effort was made to rectify the delayed start the project was brought back onto schedule. The research conducted into all of the planned tasks progressed well with promising results.

The project has progressed to plan; partner attendance has been good at all of the scheduled and working party meetings. The consortium remains highly motivated with no areas of concern for the project, further post EC project meetings have been agreed. Development of a production machine is now underway with a planned launch later in 2006.

Once the patent application has been completed the production prototype will be presented at BRAU Beviale, beer and soft drinks, trade fair in Nürnberg, 15th-17th of November 2006.

PROJECT NO: FP6-508402

SAFEVEND

New generation automated fruit juice vending machine
To reduce food poisoning of the children and the working population

Co-operative Research (Craft)

Horizontal Research Activities Involving SMEs

APPENDIX 1 – Task Deliverable Reports

Final Activity Report

Date of issue of this report: May 2006

Start Date: 1st February 2004 Duration: 27 Months

Lead Contractor: Autonumis Ltd

Version 0.1

Work Package 1 – Process Science

Task 1.1 Test rig development
Task Leader Partner 5 – DAYLA

Objectives:
Design and manufacture of a research test rig for gathering data.

Progress:
The development work undertaken within this task concentrated on building up a body of knowledge relating to the juice concentrate to be used in the Safevend system and establishing various performance parameters that will be used in the development of the Safevend subsystems.

Initial research was focused around the refractive index of fruit juices and how this measurement can be used to maintain the quality of the dispensed beverage.

Figure 1. Autonumis NT dispensing machine and data loggers.

Brix Control Testing Apparatus

- RFM91 Refractometer
- Sugar% - 0 to 95 +/-0.04
- Temp compensated sugar% - 0 to 95 +/- 0.06
- Refractive index – 1.33300 to 1.52000 +/- 6x10-5

Figure 2. Brix testing apparatus

To test the behaviour of the concentrate an Autonumis dispensing machine was used in conjunction with a RF91 refractometer, both shown above. Utilising the test equipment it was possible to obtain detailed information on the behaviour of various concentrate, the results of which are shown in task 1.2.

Testing of the mixed juice required the development of a mixing head; a simple vortex system was devised. This operated using the venturi principle; whereby the water flows around the outside of the inner component, figure 3, forming a low-pressure region at the interface between the inner and body. This low-pressure region pulls the concentrate through the inner and mixes the two liquids. The design of the exterior of the inner, a helical rib profile, also encouraged the water to form a vortex, increasing the mixing efficiency. This design is shown in the CAD images, figures 3 and 4.

Figure 3. Assembled CAD model

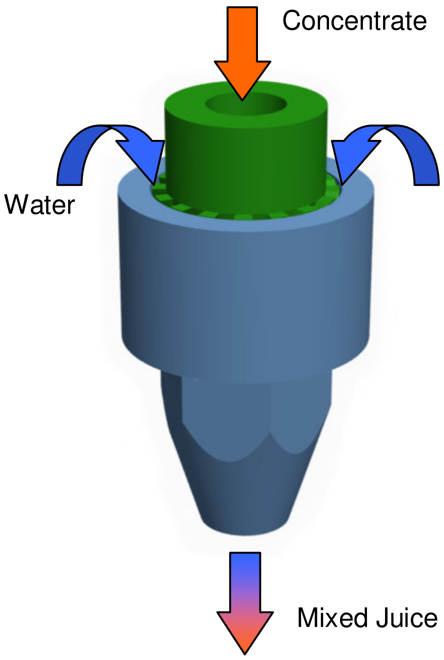


Figure 4. Cross section model

The CAD design was prototyped, figure 4, and mixed the concentrate and water very well, leaving no visible concentrate and providing a uniform consistency drink. However the prototype had certain drawbacks, the pressure provided by the water, travelling on the outside of the inner, was quite low. This reduced the amount of concentrate pulled through the inner. Suction was vastly improved if the flow of the water and concentrate was switched. So the water travelled through the centre of the inner and the concentrate flowed around the outside. This did, however, raise cleaning issue as the concentrate was now travelling around the helical ribbed surface.

Figure 5. Prototype

Task 1.2 Model of Brix Control Mix
Task Leader Partner 5 – DAYLA

Objectives:
To establish refractometer characteristics for sample juices.

Progress:
The initial tests were performed to establish the characteristics of concentrate juices. The tests results are depicted as a Brix measurement, the Brix scale represents the percentage of dissolved sugar, by weight, in a solution at a specific temperature.

Tests on samples of orange concentrate were carried out through a range of temperatures in order to establish the effects upon refractometer data.

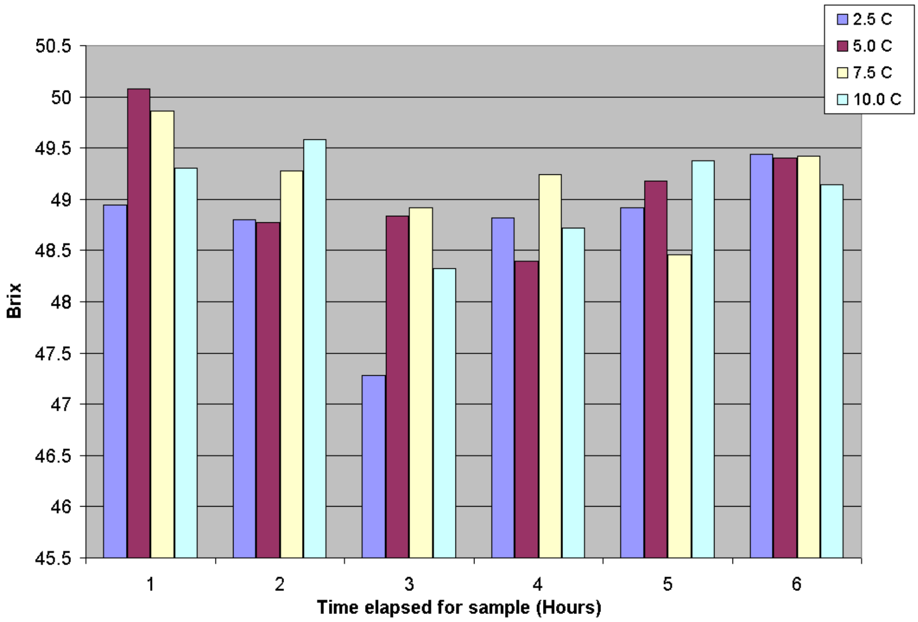


Figure 1. Brix readings taken from orange samples at a range of temperatures

The results of the temperature variation test on orange concentrate show some rather unexpected results. It would be expected that the as the concentrate cools, it becomes more dense, and thus the Brix value rises, reflecting the increased density of the liquid. However as can be seen from figure 1 this trend was not evident. It was thought that as the concentrate was derived from pulp, these large solids were settling over time resulting in erroneous readings.
In an attempt to stabilise the results the samples were allowed to settle, over a six-hour period, and Brix measurements taken on the hour. Of the six samples taken only the final sample gives the results that would be expected.

Further tests were carried out to help confirm the behaviour of the orange concentrate. These tests were carried out on two very different juices that represented the broad range of properties to be found in fruit concentrates. These two concentrates were apple and orange. Apple concentrate is a translucent liquid with a uniform consistency compared with Orange concentrate which opaque and contains a large proportion of pulp.

The graph below (figure 2) displays the refractive index measurements from a sample of apple concentrate. The Brix measurements, obtained from the concentrate, are very consistent with a maximum reading of 54.88 Brix and a minimum of 54.84, showing a deviation of 0.02 Brix.

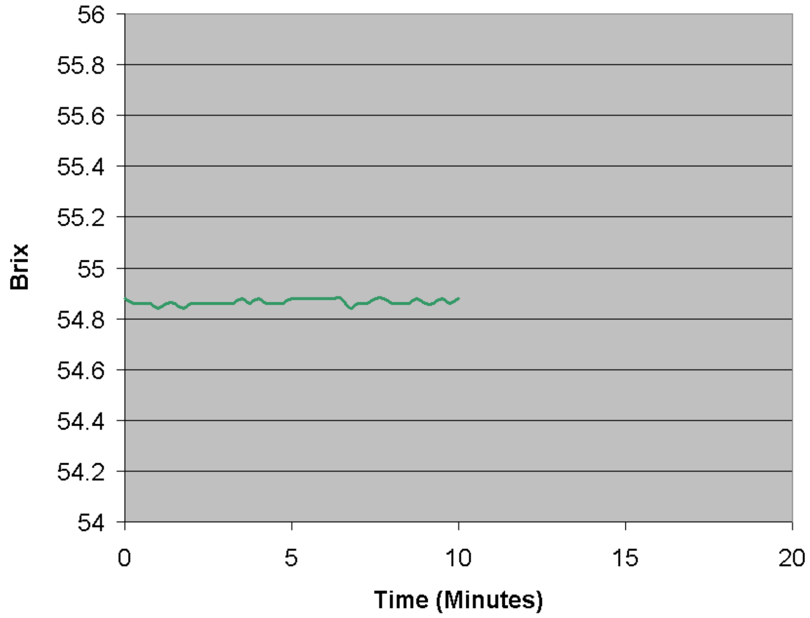


Figure 2. Brix deviation for Apple concentrate

Following the tests on Apple concentrate the same tests were performed on the Orange sample, the results of which are shown in figure 3 below. The Orange concentrate measurement shows quite a variation in the Brix readings, with a maximum of 50.08 and a minimum of 49.72, giving a variation of 0.36. The trend line, shown in figure3, forms a similar profile to that found in readings from figure 1. The readings begin high, then fall and eventually start to level out to wards the later sets of data.

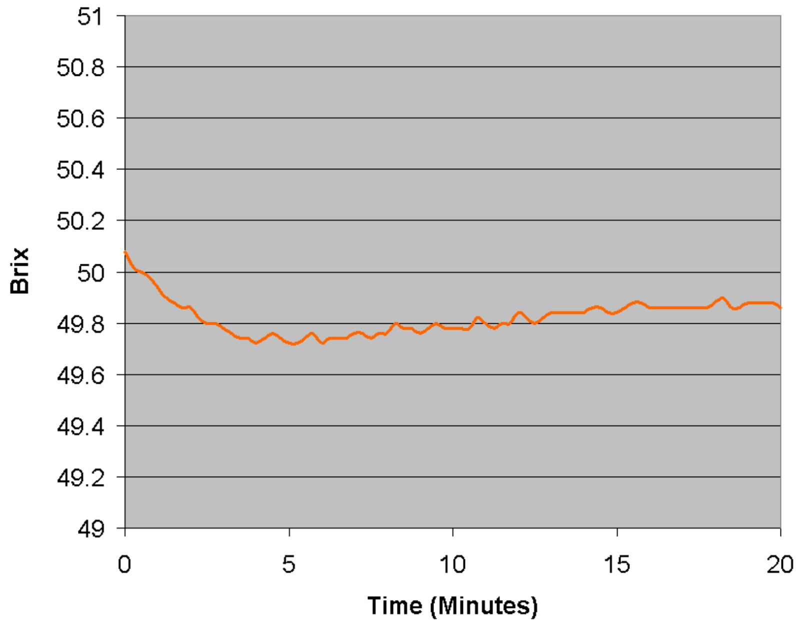
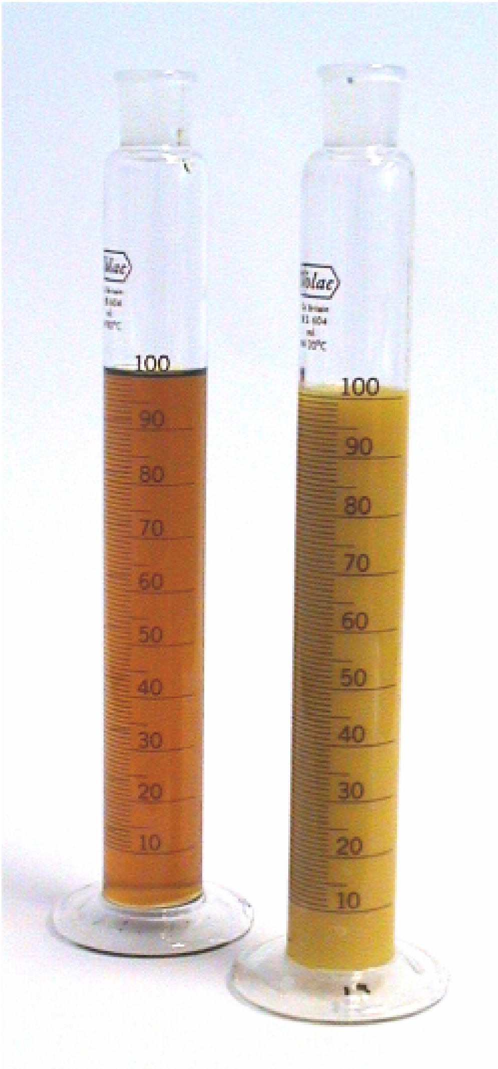


Figure 3. Brix deviation for Orange concentrate

Given the variation between the two concentrates it was important to identify the reasons for these changes in the Orange sample. It was proposed that as the Orange concentrate is derived from pulp, the pulp could be settle during the tests and thus leading to variations in the Brix readings. To this end an experiment was devised in an attempt to establish if settlement was occurring.



Settlement Test:

- 6 test samples for both Orange and Apple were created in identical laboratory test tubes.
- The samples were allowed to settle for 48 hours.
- Samples were taken, from the test tubes, using capillary tubes.
- Sample intervals, 0, 20, 40, 60, 80 & 100ml.

Figure 4. Settlement test

Figure 5 gives the results obtained from the Apple concentrate, the trend lines are reasonable consistent showing no settlement and a deviation of only 0.24 Brix between the maximum and minimum readings.

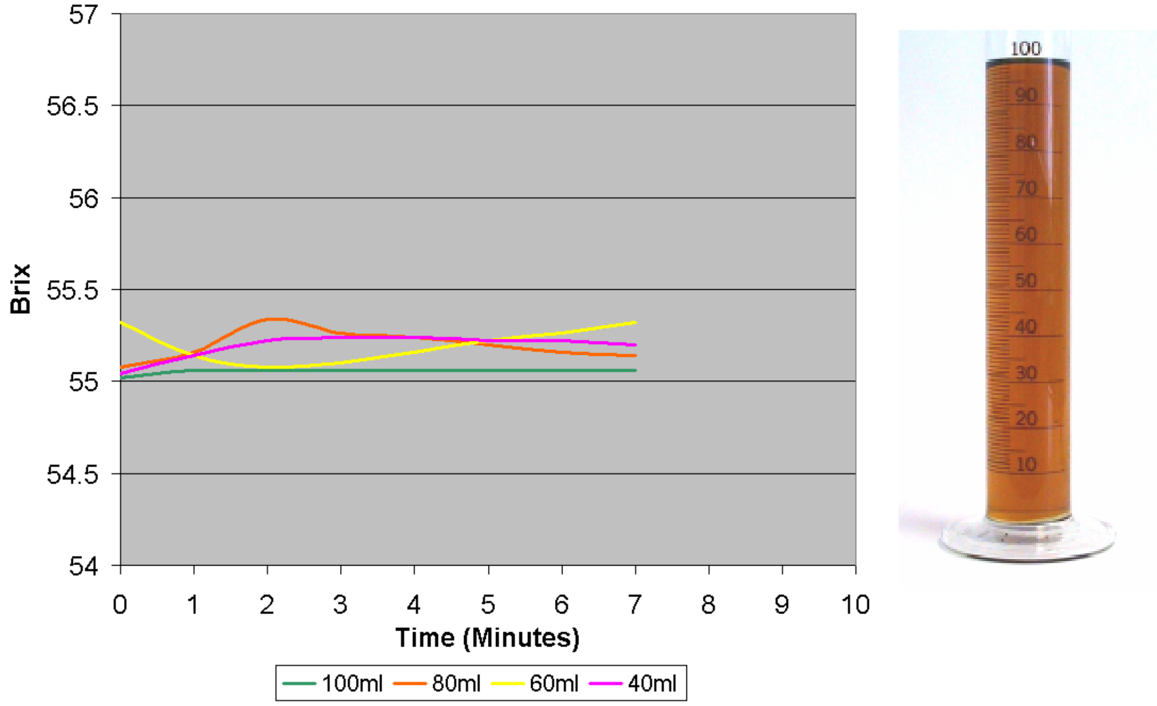


Figure 5. Settlement test on Apple concentrate

The same tests were performed on the Orange samples with very different results, as can be seen in figure 6.

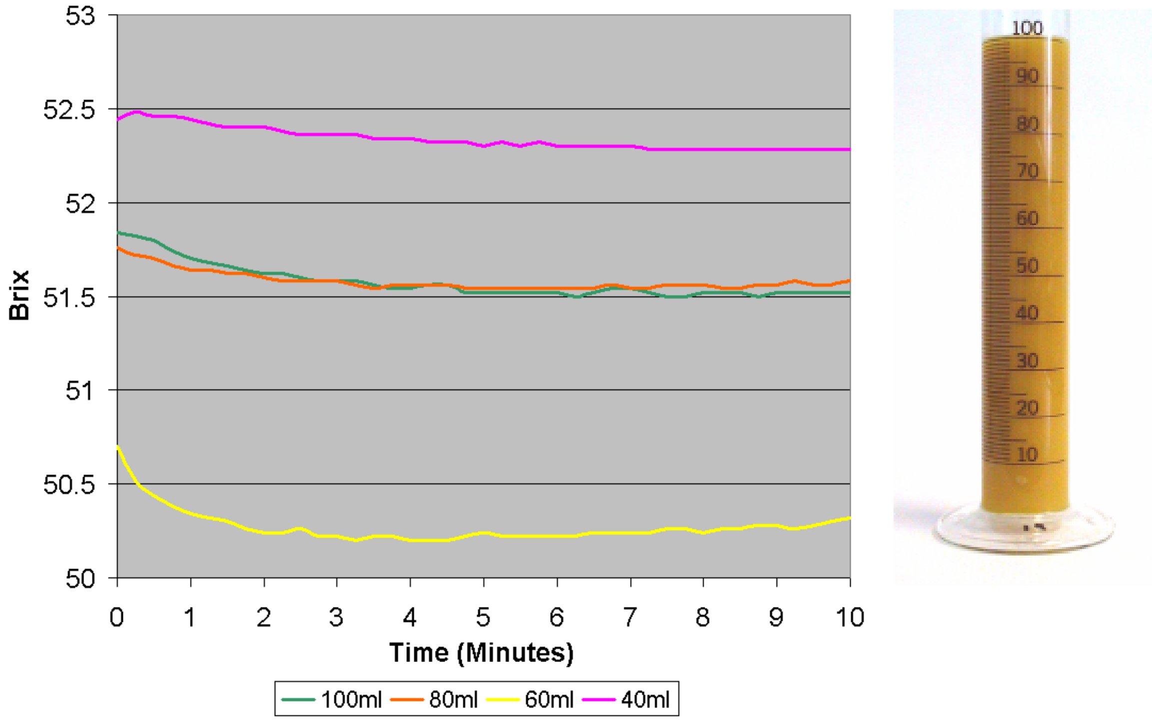


Figure 6. Settlement tests on Orange concentrate

The results of the settlement tests on the orange concentrate sample showed massive deviation in the Brix readings with a 2.28 deviation between the highest and lowest reading, compared with only a 0.24 deviation for the apple data. As can be seen from figure 6 the settlement does not follow a typical trend, it may have been expected that the samples taken from the lowest part of the test tube had the greater concentration of dissolved solids and thus a higher Brix value. In fact no trend was identified, the only conclusion that can be drawn from the test is that the orange concentrate, with a large proportion of pulp, has a tendency to towards stratification. Whereby small areas of more concentrated liquid form and remain in a fixed position.

Temperature is one of the single most important factors influencing accurate refractometer readings and is one of the largest sources of error in measurement. The design of the juice sensing system, within the Safevend machine, will have to be capable of compensating for temperature variations when analysing the quality of the dispensed beverage. Although the temperature within the machine should be constant slight variations will be encountered.

The Brix value of a fruit juice is dependent on temperature, juice typically expands when heated (become less dense) and contract when cooled (become more dense). Thus the speed of light in a liquid increases with temperature and the Brix value therefore decreases. The graph in figure 7 illustrates the behaviour of differing concentrations at a range of temperatures.

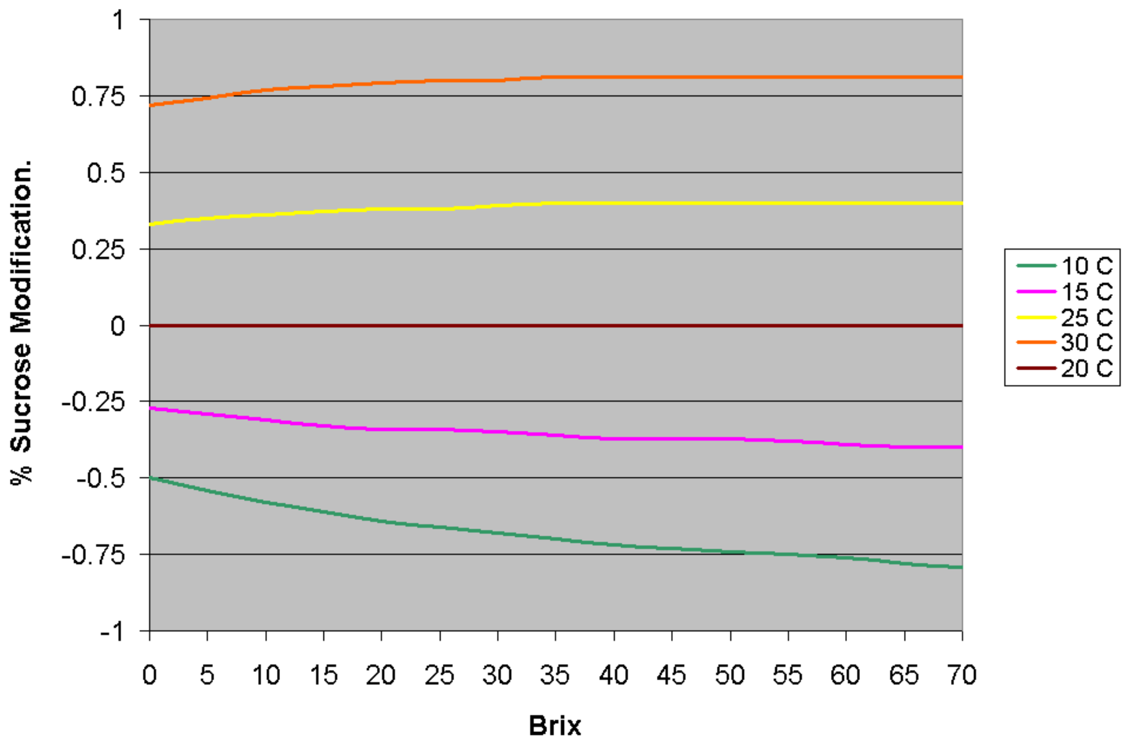


Figure 7. Brix Temperature Compensation Curves

Summary:

- Sample juices have been assessed for a range of temperatures, up to 10°C
- Refractive measurements have been made over extended time periods
- Refractometer characteristics have been established on two sample juices with very diverse properties, giving an understanding of how the range of juices will behave.
- Tables and trend lines illustrating temperature variation characteristics have been generated.

Task 1.3 New Knowledge of Refractive Index Mapping to Drinks Quality
Task Leader Partner 5 – DAYLA

Objectives:
Refractometer tests on juices to establish refractometer measurements. The establishment of a relationship between refractive index and brix measurement.

Progress:
Using the refractometer a selection of fruit juices were analysed to evaluate the Brix levels for the juice as reconstituted from concentrate at a ratio of 1 part concentrate to 5 parts water. The data in the table below, shown in figure 1, was drawn up through research with Dayla.

Juice	Brix	Juice	Brix	Juice	Brix
Apple	11.2	Grape	15.9	Peach	10.0
Apricot	11.2	Grapefruit	10.0	Pear	11.9
Banana	20.0	Lemon	8.0	Pineapple	12.8
Black currant	11.6	Lime	8.0	Pomegranate	12.0
Blackberry	8.8	Mango	15.0	Raspberry	7.0
Blueberry	10.0	Melon	8.0	Red currant	10.0
Cherry	13.5	Orange	11.2	Strawberry	7.0
Cranberry	10.0	Passion fruit	13.5	Tangerine	11.2

Figure 1. Brix data for juices reconstituted from concentrate.

The specific Brix values indicated above will allow for a specific set point to be identified when altering the concentrate/water mix ratio. As the Brix values for the juices have been identified, a relationship between the refractive index and the brix measurement also has to be established.

Figure 2 gives data logging juice refractive characteristics for each Brix value representing a full range of dilution ratios. This Refractive Index is taken from a light wavelength of 589.3nm and at a temperature of 20°C. The temperature compensation table, from task 1.2 – figure 7, can be used in conjunction with the Brix conversion table to provide temperature compensated Refractive Index readings from the juice.

Refractive Index 20°C 589.3nm	Brix %	Refractive Index 20°C 589.3nm	Brix %	Refractive Index 20°C 589.3nm	Brix %
1.332986	0.00	1.384775	32.00	1.451134	64.00
1.334420	1.00	1.386610	33.00	1.453478	65.00
1.335864	2.00	1.388458	34.00	1.455839	66.00
1.337320	3.00	1.390322	35.00	1.458217	67.00
1.338786	4.00	1.392200	36.00	1.460613	68.00
1.340264	5.00	1.394092	37.00	1.463026	69.00
1.341753	6.00	1.396000	38.00	1.465456	70.00
1.343253	7.00	1.397922	39.00	1.46790	71.00
1.344765	8.00	1.399860	40.00	1.47037	72.00
1.346289	9.00	1.401813	41.00	1.47285	73.00
1.347824	10.00	1.403781	42.00	1.47535	74.00
1.349371	11.00	1.405764	43.00	1.47787	75.00
1.350930	12.00	1.407763	44.00	1.48040	76.00
1.352501	13.00	1.409777	45.00	1.48295	77.00
1.354084	14.00	1.411807	46.00	1.48552	78.00
1.355679	15.00	1.413853	47.00	1.48811	79.00
1.357287	16.00	1.415915	48.00	1.49071	80.00
1.358907	17.00	1.417993	49.00	1.49333	81.00
1.360539	18.00	1.420087	50.00	1.49597	82.00
1.362184	19.00	1.422197	51.00	1.49862	83.00
1.363842	20.00	1.424323	52.00	1.50129	84.00
1.365513	21.00	1.426466	53.00	1.50398	85.00
1.367197	22.00	1.428625	54.00	1.5067	86.00
1.368894	23.00	1.430800	55.00	1.5094	86.99
1.370604	24.00	1.432992	56.00	1.5121	87.97
1.372327	25.00	1.435201	57.00	1.5149	88.99
1.374064	26.00	1.437427	58.00	1.5177	89.99
1.375815	27.00	1.439669	59.00	1.5205	90.99
1.377579	28.00	1.441928	60.00	1.5233	91.98
1.379357	29.00	1.444204	61.00	1.5261	92.96
1.381149	30.00	1.446497	62.00	1.5289	93.93
1.382955	31.00	1.448807	63.00	1.5318	94.94

Figure 2. Data for juices refractive characteristics for the full Brix range

Task 1.4 - New Knowledge into Microbial Contamination
Task Leader Partner 5 – DAYLA

Objectives:
Lab tests to evaluate contamination.

Progress:
As long as fruit juices are concentrated the microbiological risks are low. Fruit concentrates are pasteurised, evaporated and hot filled. These concentrates are of low pH and low water activity (a_w) and are therefore microbiologically stable.

Water activity (a_w) instruments measure the amount of free (sometimes referred to as unbound or active) water present in the sample. Water activity is a critical factor that determines shelf life.
While temperature, pH and several other factors can influence if and how fast organisms will grow in a product, water activity may be the most important factor in controlling spoilage. Most bacteria, for example, do not grow at water activities below 0.91, and most moulds cease to grow at water activities below 0.80.

Heat resistant fungal *Ascospores* can survive pasteurisation, but these cannot grow at the reduced aw of the product. Occasionally, however, the osmotolerant yeast *Zygosaccharomyces rouxii* can enter the concentrates by recontamination. *Z. rouxii* can grow and produce CO_2 at 0.62 a_w and is capable of spoilage of any liquid, concentrated food. This can result in swollen containers and risk for exploding. Spoilage is insidious, because the time to visible swelling may be many months.
In the vending machine the concentrates will be diluted by tap water to provide a drinkable juice. Dilution of the concentrate will favour the survival and growth of microorganisms in the system.

Therefore conditions which are less favourable for the survival and growth of microorganisms, as dry conditions and absence of nutritive substances should be aimed for when the machine is not in use.

Choice of products
The microbiological risks of juice concentrates are relatively low: protected by low pH, low water activity. Microflora: yeasts and moulds

The microbiological risks increase for products with pH > 4 and high a_w (e.g. milk products). Microflora: diverse (incl. pathogens), depending on the properties of the product.

Of orange juice with different concentrate levels the pH values have been measured at two different temperatures, shown below in figure 1.

Brix	5°C			30°C		
	pH	**Conductivity**	**Temp.**	**pH**	**Conductivity**	**Temp.**
66	3.58	0.503 mS/cm	4.9	3.58	1.13 mS/cm	31.5°C
55	3.63	1.5 mS/cm	5.1	3.61	2.88 mS/cm	31.3°C
48	3.66	2.96 mS/cm	4.7	3.64	4.08 mS/cm	31.6°C

Figure 1. pH values of orange concentrate

Of Orange juice with different concentrate levels the a_w-values have been measured at a temperature of 25°C, figure 2

Brix	a_w-values measured at 25°C		
	Measurement 1	**Measurement 2**	**Average**
66	0.840	0.835	0.838
55	0.898	0.893	0.896
48	0.924	0.920	0.922

Figure 2. a_w-values

The measurements show orange juice concentrates to have pH levels < 4 and at Brix level 55, as will be supplied in the bag in box for the Safevend machines the water activity is below 0.9.

The microbiological risk, as stated earlier, is relatively low if only juices are vended. If besides milk type products, with pH > 4 and high a_w, would have to be vended this would have a major impact the design of the machine and the special cleaning operations.

Choice of the type of products to be vended with the machine will have a large affect on the cleaning procedures

Storage of concentrates in the vending machine:

Storage at ambient temperature might affect the quality of the stored concentrate through physical, chemical, and possible microbial changes. This depends on the nature of the juice concentrate. Therefore cooling of the concentrates at lower temperatures is recommended.

Recontamination after opening bag in box:

Recontamination of the concentrate after opening the box is an important issue, which will have to be addressed in the design.

It may appear though:

Connecting the box to the hose and/or to the machine.

It depends on the nature of the product whether there are opportunities for microbial growth.

Backwards flow into the bag. Contamination in combination with dilution of the concentrate might lead to (local) growth of microorganisms.

Cleaning and disinfection:

Cleaning is a very important issue. During cleaning remnants of products should be removed effectively to avoid caramelisation and denaturation during thermal disinfection. In addition, remnants of product decrease the efficacy of disinfection. So called "dead spaces" in the design of the machine should be avoided as the flow of the cleaning medium will be unsatisfactory or will not even reach these places.

Different kind of products (in one machine) will lead to different sorts of soiling; this might require different cleaning procedures. For example, to remove proteins, a two-phase cleaning method is required (low temperature, followed by high temperature cleaning).

During thermal disinfection other areas in the machine will also be warmed up. When the temperature of the concentrate rises, this might affect the quality of the product. Cold and hot areas during thermal disinfection might lead to condensation; this might favour microbiological growth in/out the machine after disinfection.

Heating requirements for disinfection of vending machines dispensing fruit juices

In the food industry several levels of hygienic conditions are used that should be maintained when filling certain products. Some of these categories are:

- Aseptic conditions in case of filling neutral pH sterilized products to be stored without refrigeration.
- Ultra clean conditions for neutral pH pasteurised products to be stored refrigerated for a limited time,
- Clean conditions for low pH (< 4) pasteurised products.

In case of aseptic conditions the product, filling machines and packaging material should be carefully sterilized and the environment should have a very low contamination level (ISO 5). In this situation pathogenic bacteria as well as spoilage microorganisms should be absent in the final product.

Ultra clean conditions should result in low quantity of microorganisms in the final product. Sterilization of the filling equipment is often necessary and the environment should have a low contamination level (ISO 7). Infectious pathogenic bacteria should be absent in the final product. Survival of bacterial spores in the product is allowed below a certain predetermined level and contamination with spoilage microorganisms should be kept at a minimum level.

Clean conditions are prescribed in case of microbiologically more stable products like low pH drinks and fruit juices. Because bacterial spores cannot germinate at such low pH values pasteurisation of filling machines will be sufficient in most cases. Also less stringent demands concerning environment have to be maintained (ISO 8). Pathogenic infectious bacteria and spoilage microorganisms should be practically absent in the final product but complete elimination of microbial spores is not necessary.

The vending machine, under development in the Safevend project, is to be used for dispensing fruit juices only. Since these products do have pH values below 4 and the fruit juice is refrigerated in the machine the cleaning and disinfection demands will be those necessary for clean conditions. A regular cleaning of the dispensing unit and pasteurisation with hot water or steam to reach a minimum temperature of 70℃ for at least 2 minutes at all places will be sufficient (P70 is 2 minutes; z value is 6℃). In case of longer holding times after cleaning and disinfection without fruit juice, dry circumstances are preferred. For this situation sterilization with overheated steam of at least 110℃ is recommended.

Alternatively the dispensing unit might also be designed as a replaceable unit that can be cleaned, disinfected and dried outside the vending machine. The advantage will be a less complicated filling machine and a more easy way of cleaning and disinfecting the dispensing unit.

Additional information related to European Hygienic Equipment Design Group EHEDG can be found on the project webpage. EHEDG is an independent consortium formed in 1989 to develop guidelines and test methods for the safe and hygienic processing of food. The group includes representatives from research institutes, the food industry, equipment manufacturers and government organisations in Europe

Project Web Page – European Hygienic Equipment Design Group (EHEDG):

- In-Place Cleanability Test Of Food Processing Equipment (EHEDG Doc 2)
- In-Line Pasteurisation Test Of Food Processing Equipment (EHEDG Doc 4)
- In-Line Steam Sterilisation Test Of Food Processing Equipment (EHEDG Doc 5)

Concepts of vending machines:

To get a first impression of how the vending machines may look like and to use as material for discussion within the Safevend team various concepts of it have been designed by TNO.

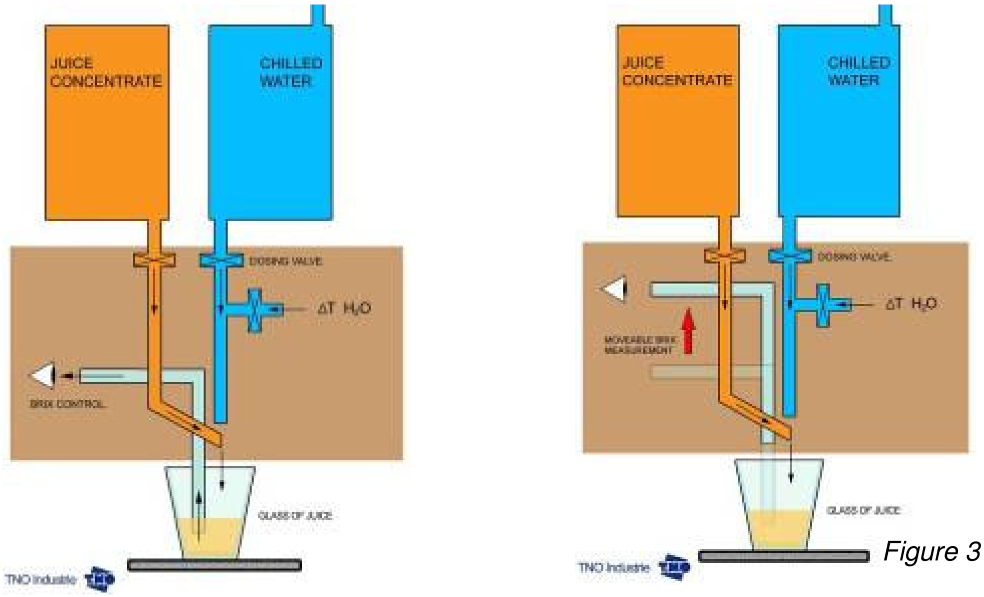


Figure 3

Figure 3 shows a concept in which concentrate is directly dispensed into the glass. Both the concentrate and the water have the vending temperature. The water to dilute the concentrate flushes over the outlet of the concentrate preventing the build up of remnants of the concentrate. The Brix level is controlled by an optical sensor which by rotating provides the mixing of the concentrate with the water. Before completion of the drink preparation the sensor is moved upwards and at the same time flushed by water.

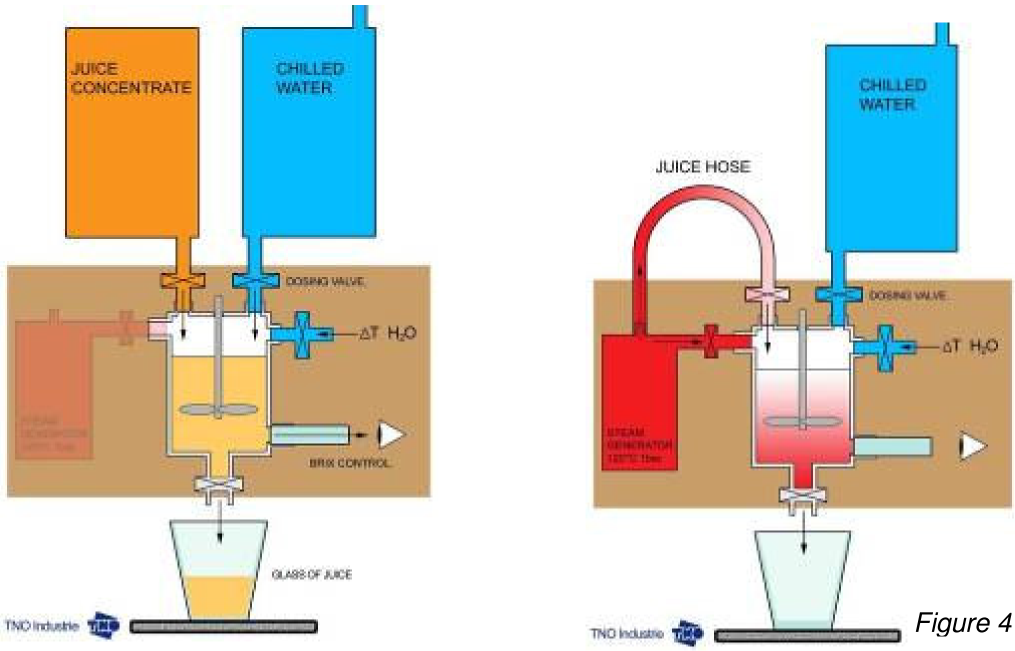


Figure 4

Figure 4 shows a second concept of a vending machine. Concentrate is dispensed and chilled water is added and mixed as much as needed to match the required Brix index. To be able to control the temperature of the vended juice, water with a different temperature can be added to compensate the ΔT. Before placing a new concentrate bag is placed in the machine all surfaces have to be heated up to 90℃ minimum for 5 minutes. The heat will be provided by overheated steam of 120 ℃. This type of steam will result in dry disinfected surfaces leading to minimal growth of microbes and no germination.

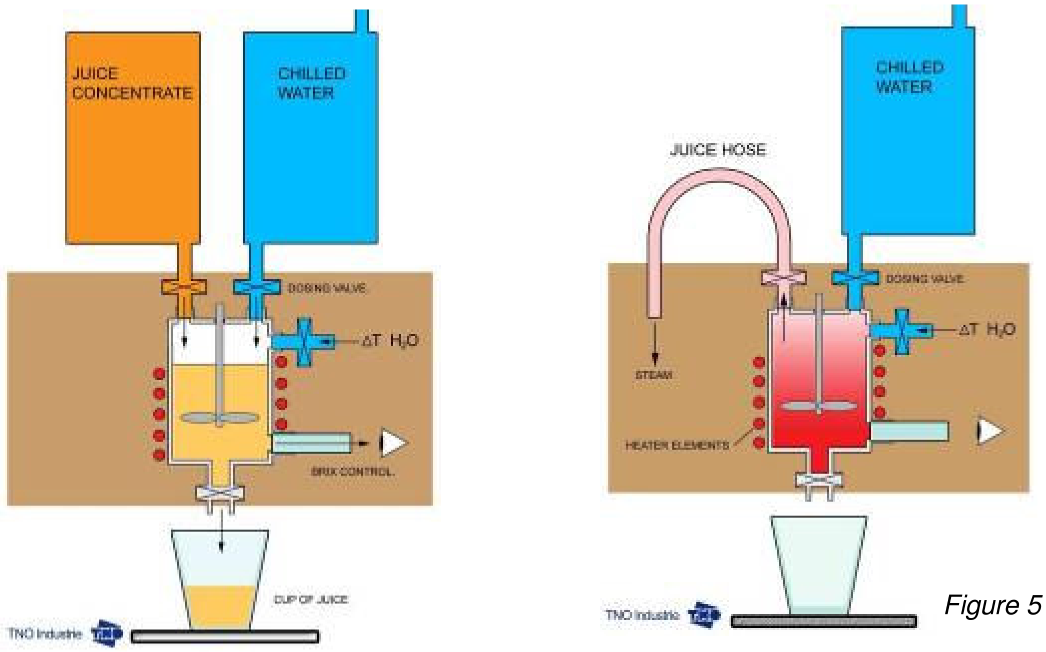


Figure 5

Figure 5 shows a variation of the second concept. In this concept the mixing chamber is used as chamber to build up the overheated steam.

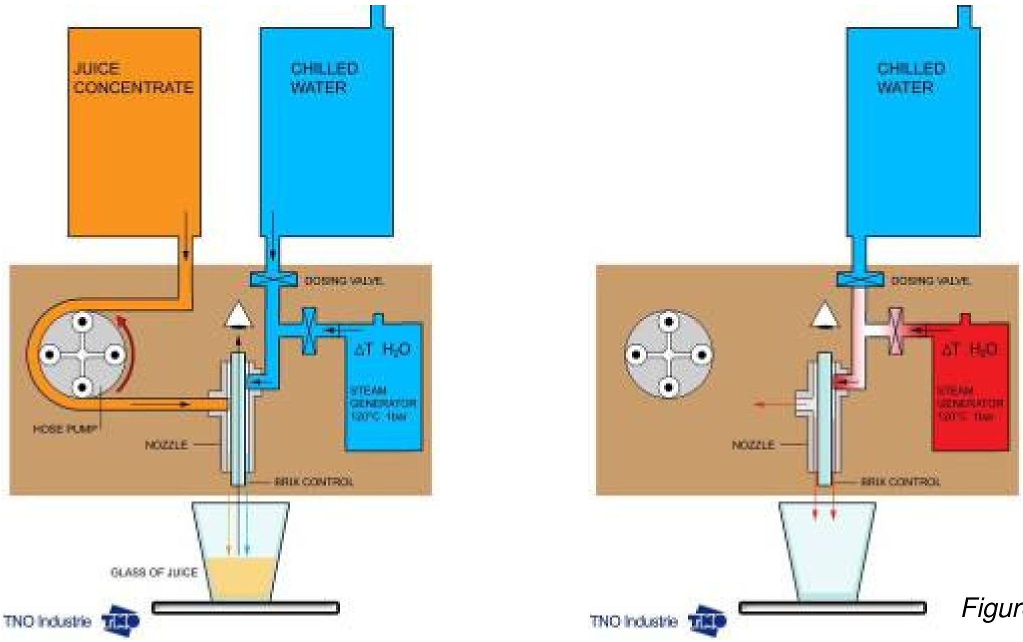


Figure 6

Figure 6 shows a third concept of a vending machine in which the concentrate is actively dispensed by means of a roller pump. The silicone hose will be replaced when a new bag in box is installed.

Design recommendations minimize microbiological contamination and growth

- Proper and easy cleaning of machine before installation of a new bag in box
- Minimize the possibility for contamination during installation of new concentrate
- Prevent possibility for backflow into bag in box
- Cooling of concentrate at lower temperature
- Minimize the contact surfaces areas.
- Maximize flushing out of concentrate after mixing
- Drying of surfaces after dispensing of juice
- Prevent dead spots in system
- Thermal disinfection of system before installation of a new bag in box.

Before installing any vending system, it is essential to know the product requirements of the future product, the concentrate type, which will be vended, the functional build up of the machine and the environment in which it will have to operate. Therefore the emphasis has been put on assisting in the creation of product specification. As soon as the specification is agreed upon, a test-rig providing the required functionality will be build for the required testing. This task will be completed in the next three months.

All the required measurement methods are described in the EHEDG (European Hygienic Equipment Design Group) Doc 2, March 2000, 'A method for the assessment of in-place cleanability of food processing equipment'. A copy of which can be found on the Safevend website. The test protocol will have to be adjusted to match the test criteria for this type of machines.

The design of the vending machine will have to meet the EHEDG Doc 8. Hygienic equipment design criteria. A copy of which can be found on the Safevend website.

<u>Work Package 2 – Brix Control Unit</u>

Task 2.1 Refractometer and Control Development
Task Leader Partner 2 – BCN

<u>Objectives:</u>
The design and development of a measurement control mechanism.

<u>Progress:</u>
Measurement mechanism:
Using the test results form task 1.2 and through discussions with BCN it became evident that refractometry, used to monitor and control the juice quality, wasn't the most appropriate technology. Light absorption was suggested, as alternative, which could perform the same functions as the refractometer but using fewer components and at a fraction of the cost. This concept was introduced to the consortium at the month 6 meeting.

The standard method of measuring the quality and concentration of fruit juice is using the Brix scale. The Brix scale represents the percentages of dissolved sugar by weight in a solution at a specific temperature. In the beverage industry, control of brix affects the cost, taste, and quality of the drink product.

Refractometer is the most common method of brix assurance for the food industry as they are very accurate and easy to use. The refractive index (nD) is obtained by measuring the critical angle of a light beam hitting the sample. At this critical angle no more light is refracted, the entire beam is reflected. This total reflection is detected by a high-resolution optical sensor and converted into refractive index, BRIX or user specific concentrations. As can be seen from figure 1, the refractometer uses many components including a prism, which must be manufactured to a high tolerance and an array of 256 photodiodes. The alternative technology, light absorption, determines the concentration of a solution by measuring the amount of light transmitted through a sample at specific wavelengths. Light from a LED light source passes through a cuvette containing a solution sample, as shown in the diagram below. Some of the incoming light is absorbed by the solution. As a result, light of a lower intensity strikes a photodiode. This method utilizes three basic components, a LED, cuvette and one photodiode as can be seen in figure 2.

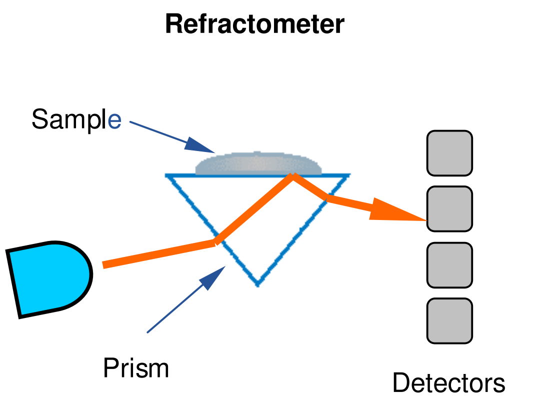


Figure 1

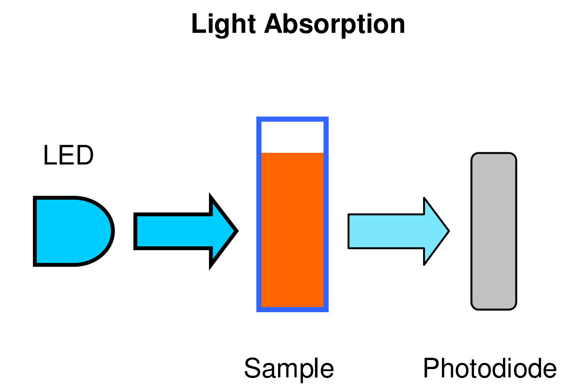
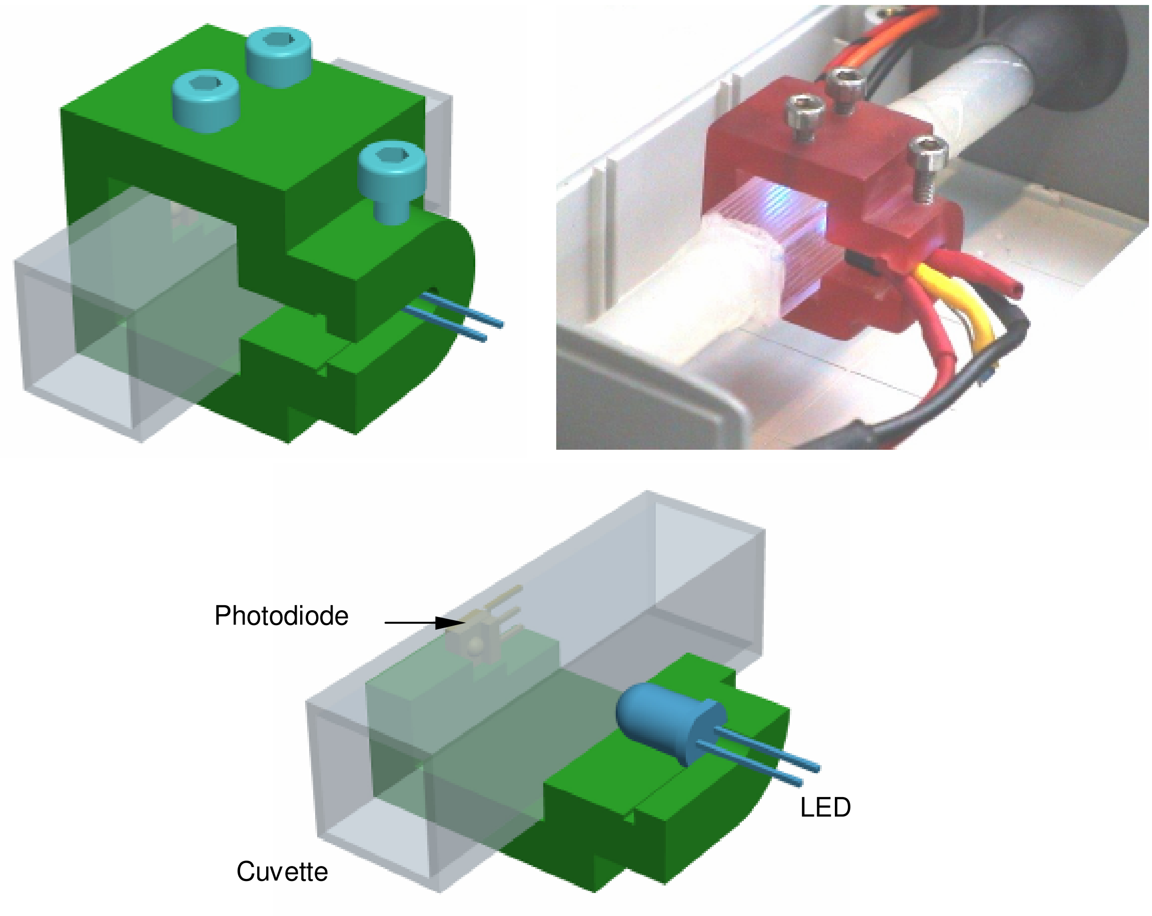


Figure 2

A simple test chamber was developed to assess the feasibility and repeatability of the light absorption technology, figure 3. This consists of a rapid prototype jig manufactured using Stereo Lithography process. Into this were placed a photodiode and LED. These were temporarily screwed into place to allow testing of alternative components to identify the most suitable. A clear acrylic cuvette was the placed between the LED and photodiode. This chamber had to maintain the relative position of the LED and photodiode accurately. As any slight deviation would alter the amount of light directed onto the diode and thus invalidate the repeatability of the tests.

Once the test chamber had been assemble it was sealed so that changes in ambient light could not influence the results. Tests were performed firstly on static juice samples and then samples of juice flowing at approximately 60 litres per hour, the final machine specification, to assess the repeatability and robustness of the sensors.

Figure 3. 3D CAD model of the jig used to hold the Cuvette, LED and photodiode.



Control mechanism:

A metering and mixing system was developed to control the mix ratio, according to data from the light absorption unit. This system had to ensure that suspended solids were equally dispersed to allow for accurate readings, and that air bubbles were eliminated that could influence the light absorption readings.

The development of the mixing head progressed, from the work completed under task 1.1 where two mixing heads were developed, through two further distinct design iteration before settling on the final solution. The mixing head had to capable of mixing and metering the concentrate/water ratio whilst also using the water flow to pull through the concentrates without the need for an additional pump.

Development Head No. 3

The design of this mixing/metering head, figure 4, used a needle valve to control the mix ratio of concentrate to water. The concentrate enters the metering head and travels around the outside of the needle valve. The water flows around the outside of the needle valve creating a vacuum. When the needle valve opens, the vacuum then pulls through the concentrate. However the vacuum generated was poor and insufficient to pull through enough concentrate.

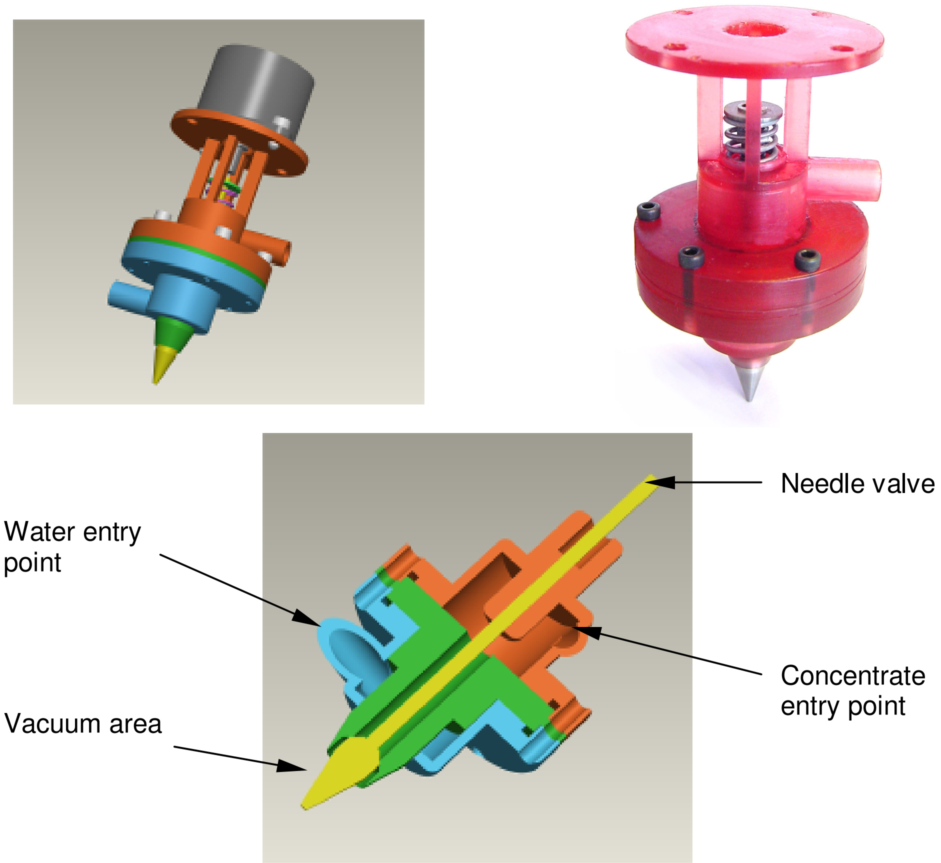
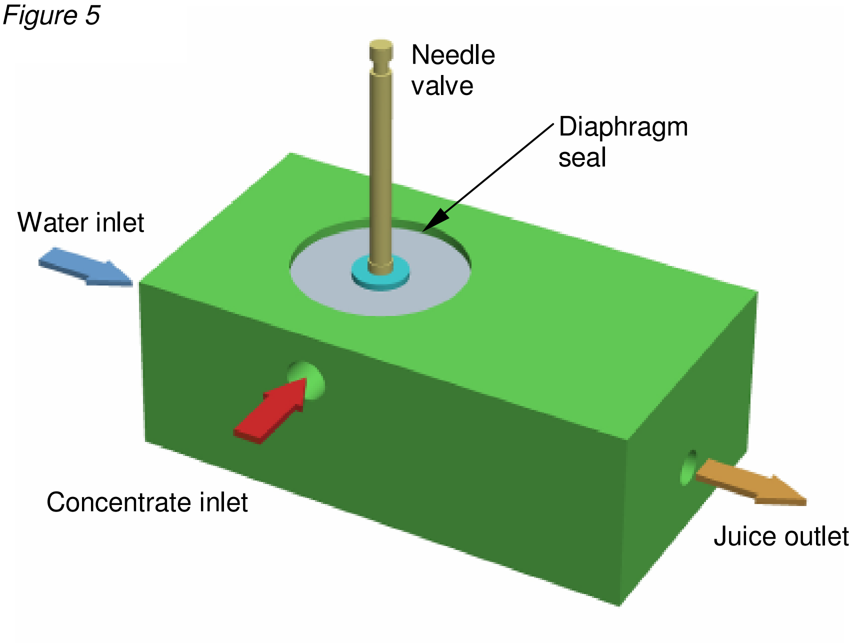


Figure 4

Development Head No. 4

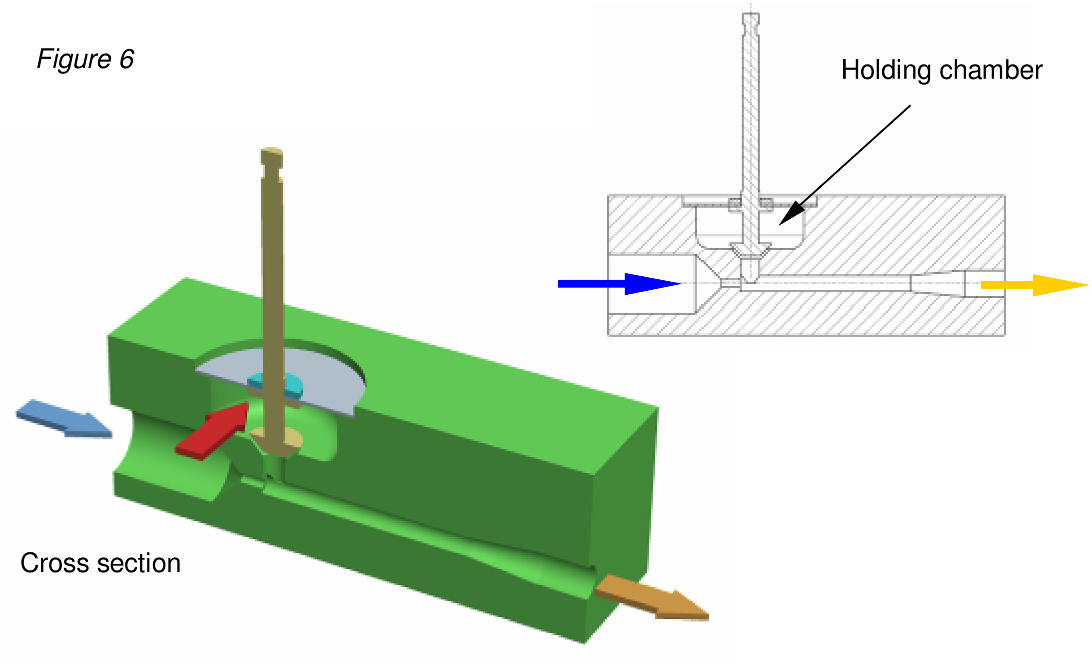
In order to ensure that an additional pump for the concentrate was not needed a further design was created, figure 5 and 6. This design utilises the Venturi principle, whereby suction is generated when a fluid passes through a narrowed channel. Water is used to generate the suction, which in turn pulls through the concentrate.

Figure 5



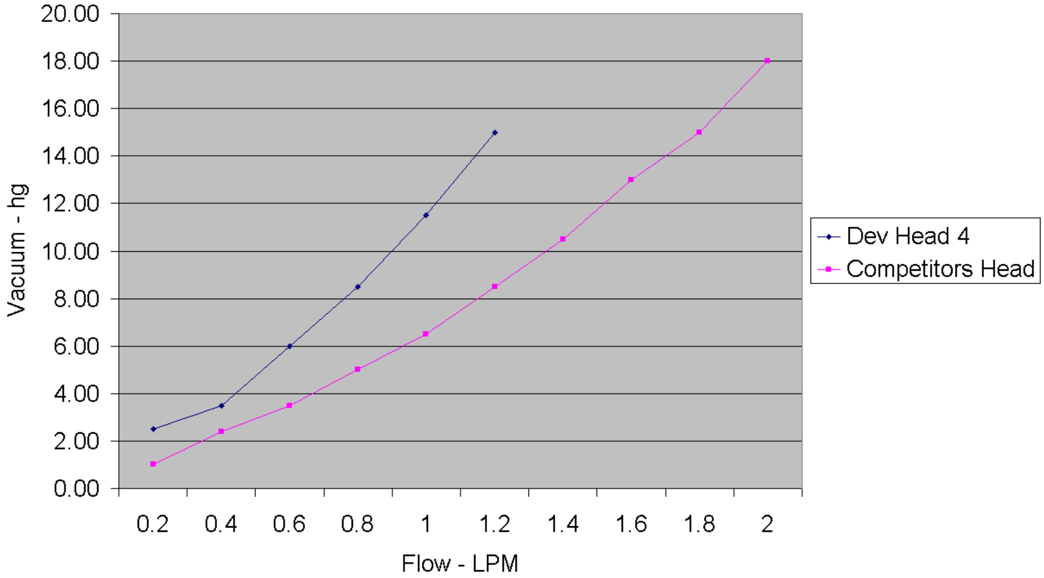
The mixing head includes a needle valve and diaphragm seal. The needle valve is normally in the closed position, this ensures that the concentrate is kept in the holding chamber and prevents any cross contamination between the water and concentrate. Once the water start to flow the needle valve is opened which allows the suction, generated by the water, to pull the concentrate through. Restricting the extent to which the needle valve is opened can modify the ratio of water to concentrate.

Figure 6



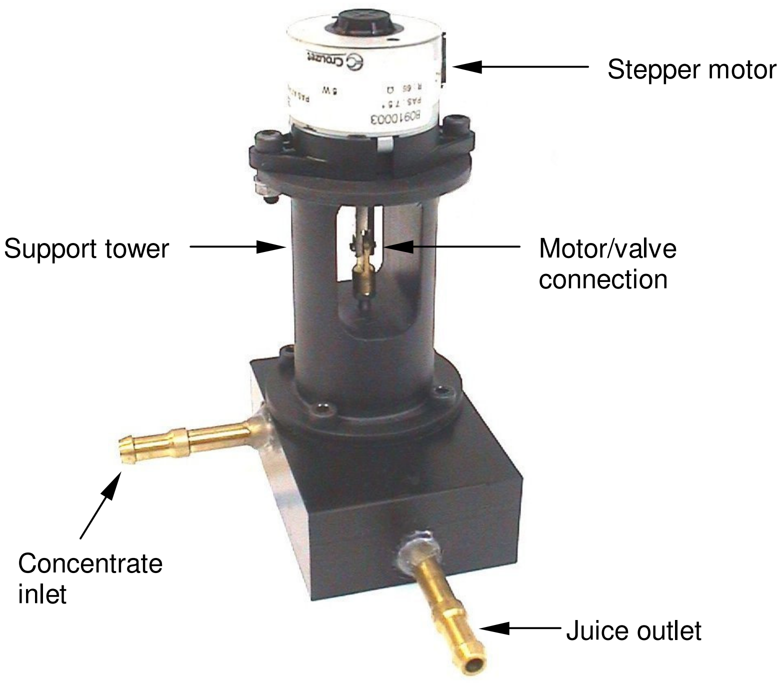
A prototype for development head no. 4 was tested and this performed extremely well. The suction generated by a water flow of 1.5 litres per minutes, taken at the concentrate inlet, measured 7.86 PSI. The Safevend mixing head provided greater suction than a similar competitors unit, which only generated a vacuum of 6.38 PSI.

Figure 7. Development head No. 4 comparison test



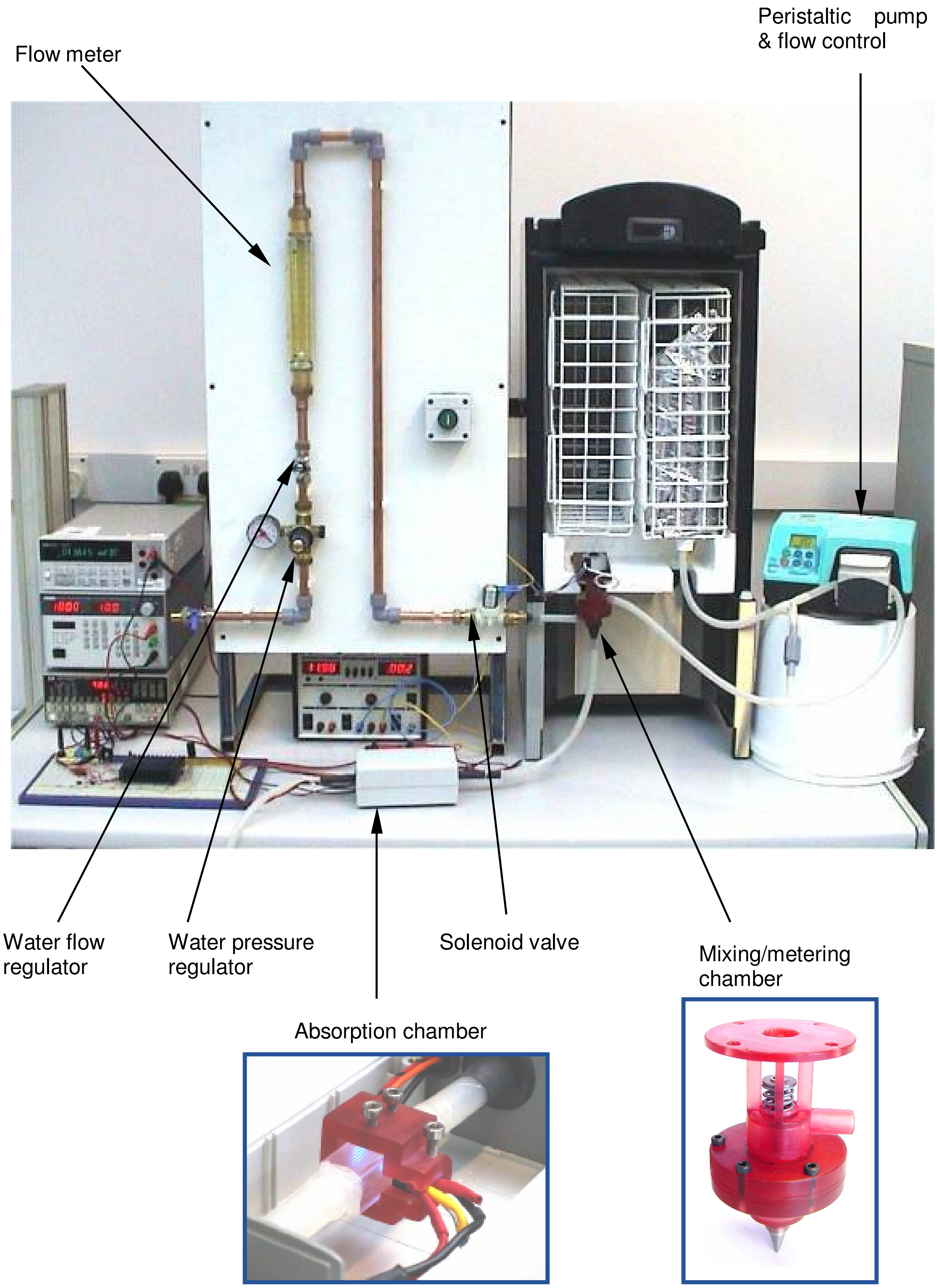
When the concentrate was connected to the mixing head it was possible to dispense a drink, relying only on the suction generated by the water at 1.5 litres per minute flow rate, to a value of 19.5 brix. This value is well in excess of the typical 11.6 brix for a juice drink.

Figure 8. Shows the prototype head with a stepper motor, used to control the needle valve.



In order to test the mixing head in conjunction with the measurement chamber a test rig was developed, figure 9. This shows the early evaluation of development head no. 4 in conjunction with the light absorption chamber.

Figure 9. Mixing/metering head and measurement chamber test rig.



Task 2.2 Brix Measurement Algorithms
Task Leader Partner 2 – BCN

Objectives:
The development of sensor and control algorithms.

Progress:
The initial test on light absorption looked into the possibility of targeting glucose contained within the juice, a concept suggested by BCN, to determine the concentration.

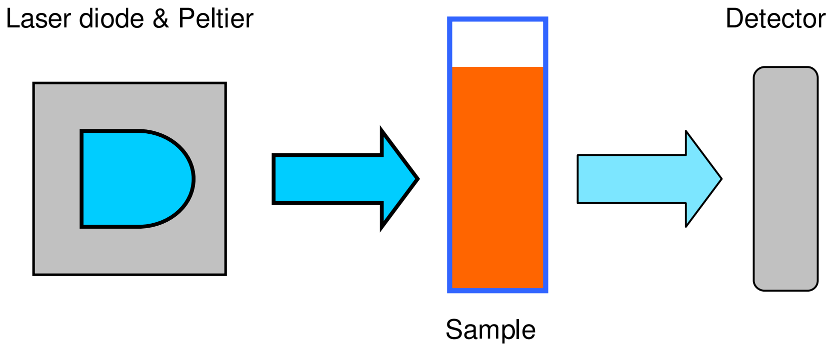
A literature study was undertaken to determine the studies that had been undertaken by others, in order to suggest infrared absorption bands of water and glucose. It was intended that this would identify the wavelengths that should be investigated. The following paper was used as a basis to start testing.

Determination of Glucose Concentrations in an Aqueous Matrix from NIR Spectra Using Optimal Time-Domain Filtering and Partial Least-Squares Regression, by Fredric M Ham et al, IEEE Transactions on biomedical engineering, Volume 44.no 6. June 1997.

The paper suggested that the near infrared spectrum would offer the best results. This would also offer the following advantages:

- Near infrared is not absorbed by water to the same extent as mid or far infrared.
- Near infra red includes the wavelength 1600nm, this wavelength is used extensively, and has been the subject of much research by the telecommunications industry, therefore the optics are small and inexpensive.

Figure 1. Schematic diagram of the set up that BCN designed for the testing of the glucose solutions.



The test rig that BCN built was designed to minimise any errors in the testing, from variability in the optics to being able to compensate for the different refractive index of the solutions. The different wavelengths are obtained by varying the voltage or the temperature of the laser. From this testing the following plots were made, the first illustrates the difference between the pure water solution without glucose and the pure water solution with 150mg/dL glucose, the second illustrates this difference as a percentage.

Figure 2. Absorption differences between water and glucose solution

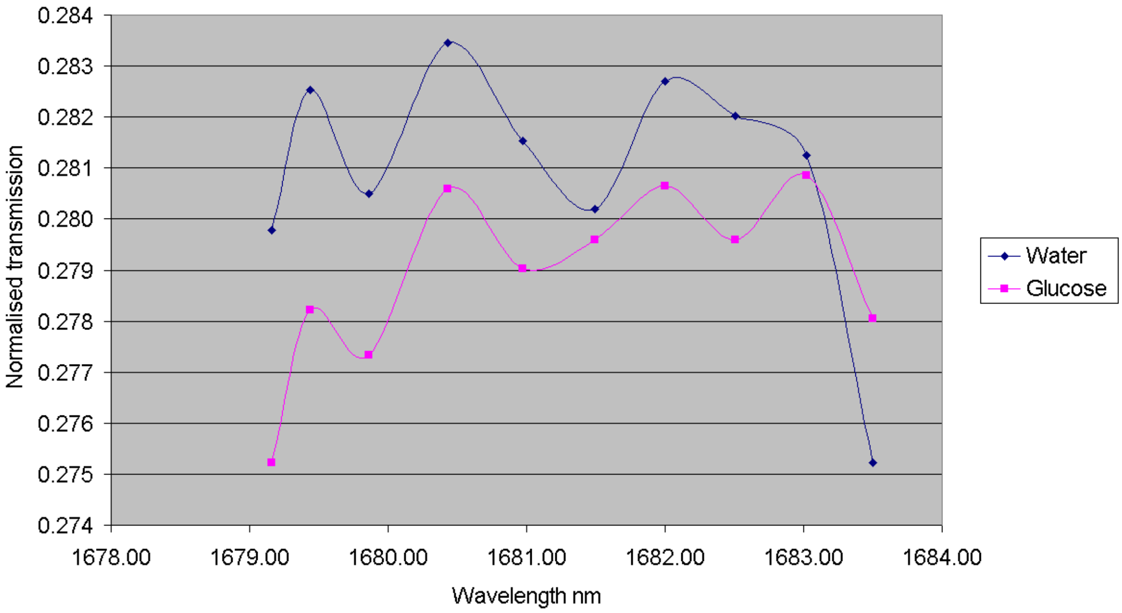
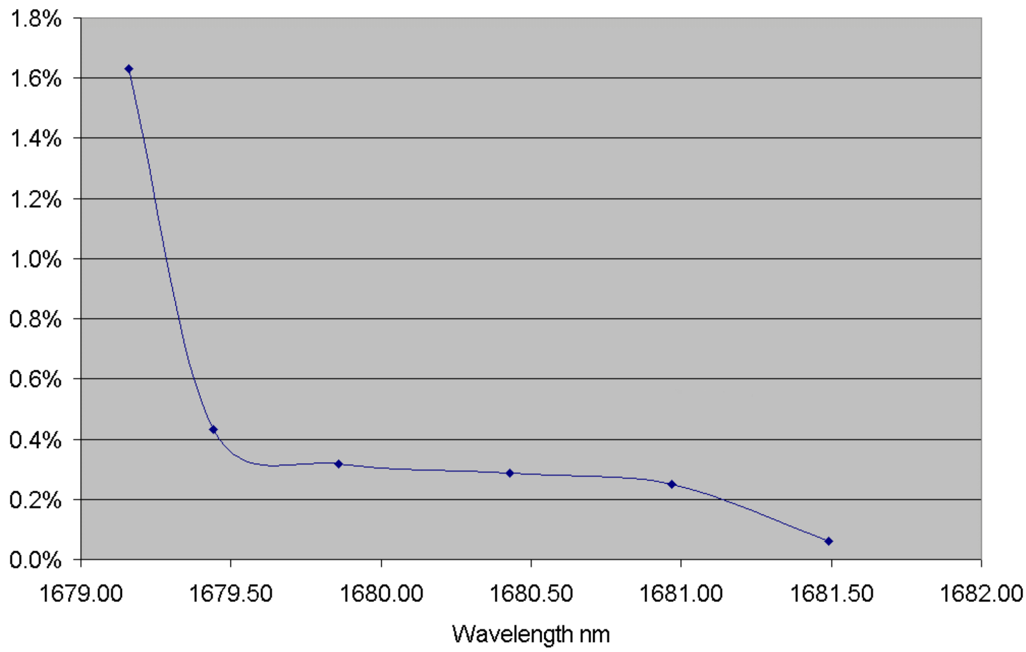


Figure 3. Percentage absorption differences between water and glucose solution



The results of the glucose absorption tests were promising and would offer a simple method of assessing the concentration levels of juice, by measuring the amount of glucose contained within the solution. However if glucose measurement were adopted then this would restrict the use of the dispensing machines to drinks containing sugar. The beverage used for the development of the dispensing machine is natural fruit concentrate, which does contain sugar, but the consortium felt that the measurement method should not be restricted to glucose.

Following the research into glucose absorption the project focused on light absorption. A light absorption chamber was developed that would hold a cuvette along with an LED and photodiode.

Initial tests were conducted on a range of light wavelengths for which LED were readily available, 428, 470, 525, 590, 629 and 650nm. As in task 1.2 these tests were carried out on two very different juices that represented the broad range of properties to be found in fruit concentrates. These two concentrates were apple and orange. Apple concentrate is a translucent liquid with a uniform consistency compared with Orange concentrate which opaque and contains a large proportion of pulp.

Test showed that 470nm was the most suitable wavelength for apple and orange, figure 4 and 5. At 5% concentration the LED supply voltage was adjusted so that the photodiode was just coming out of saturation.

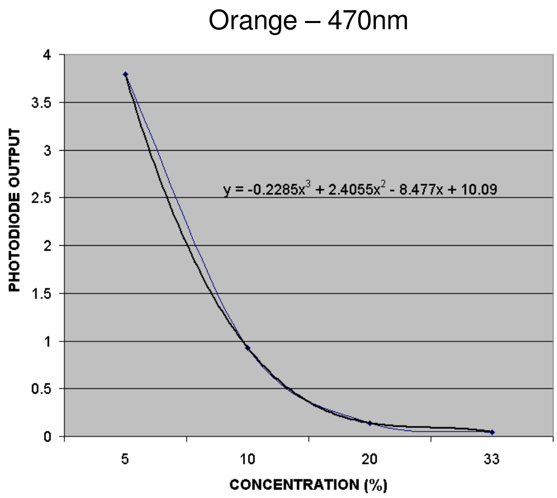


Figure 4. LED Voltage – 3.20

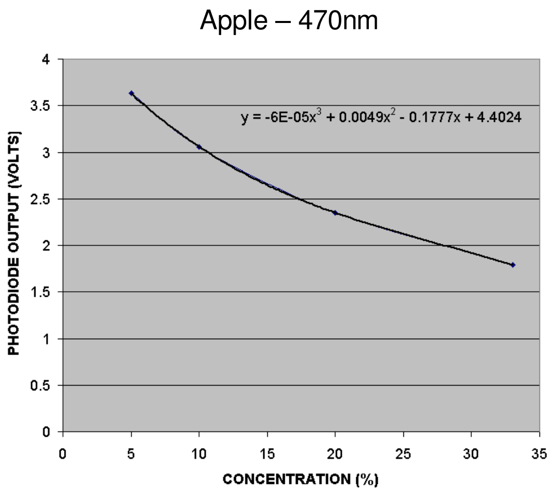


Figure 5. LED Voltage - 2.75

Regression was performed on this dynamic flow data to mathematically describe a best-fit curve to be used in designing system controller.

As the 470nm had been identified as the most suitable a relationship between the light absorption figures, measured by the photodiode, and actual Brix levels needed to be established. This relationship can be seen in figure 7.

Figure 6. Transmission against concentration

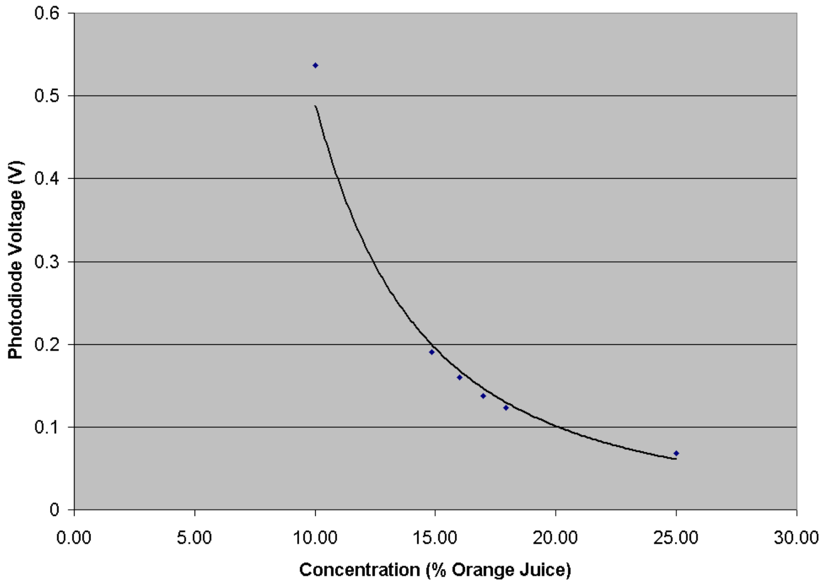
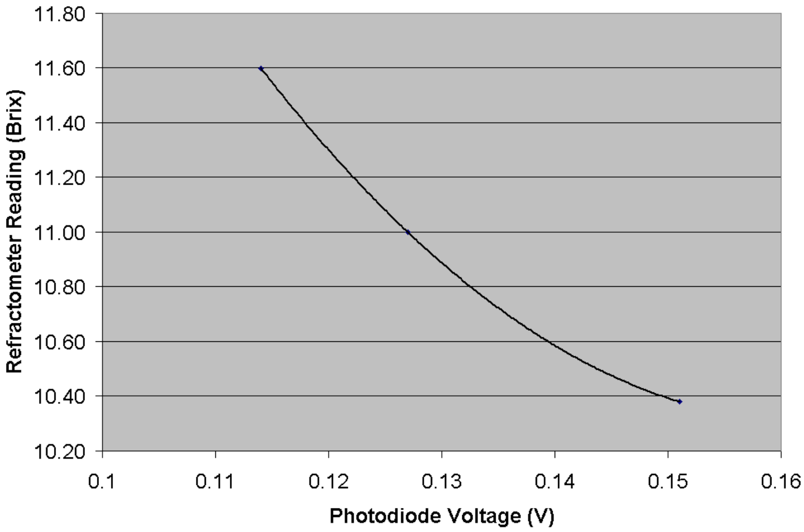
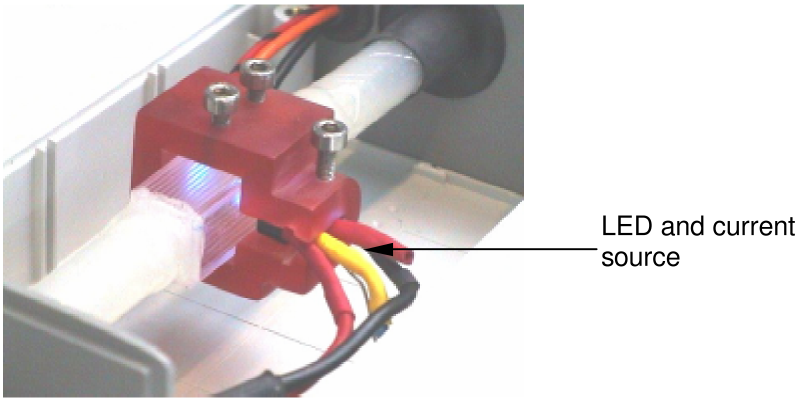


Figure 7. Light absorption compared to Brix



Although the measurement system should be maintained at a constant temperature, in the same environment as the concentrate, it was felt necessary to include a temperature compensation system. This was achieved by placing the current source, which drives the LED, physically in contact with the LED, figure 6. Current source temperature coefficient is equal and opposite to that of the LED.

Figure 6. Light absorption chamber

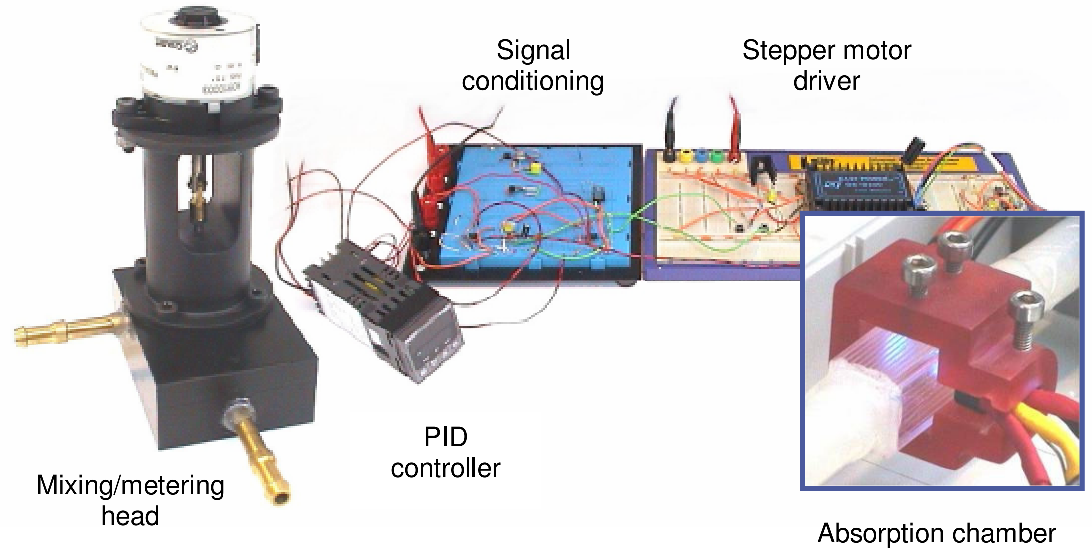


Task 2.3 Hardware Implementation and Tests
Task Leader Partner 2 – BCN

Objectives:
The aim of this task was to complete the hardware implementation and testing on sample juices.

Progress:
Data received from the measurement chamber was used to control the mixing/metering head; in turn the measurement chamber monitored the effects of the changes to further modify the mixing/metering head. Thus the unit formed a closed loop system.

Figure 1. Closed loop hardware layout.



Mixing head control system, Figure 2:

- Set Point specifies the concentration of the mix
- PID Controller continually adjusts the Control signal until the Process signal is equal to the Set Point signal

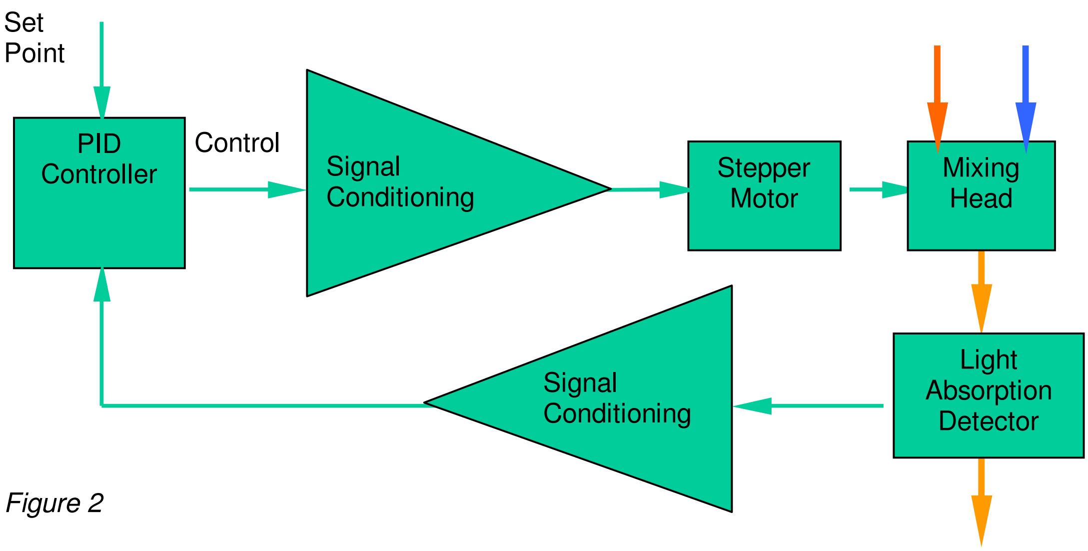


Figure 2

PID (Proportional, Integral, Derivative) algorithm parameters control the speed and shape of response to changes in the measurement chamber. This is used to automatically adjust the position of the needle valve to hold the set point for the measurement. The set point is where you would like the measurement to be.

Proportional Band:
With the proportional action controller output is proportional to the change in measurement. With a proportional controller offset (deviation from set-point) is present. Integral action is used to eliminate this offset

Integral:
With integral action, the controller output is proportional to the amount of time the change in measurement is present. Integral action gives the controller a large gain at low frequencies that results in eliminating offset and reducing load disturbances. The controller phase starts out at a negative value and increases to near 0 at the break frequency. This additional phase lag is what you give up by adding integral action. Derivative action adds phase lead and is used to compensate for the lag introduced by integral action.

Derivative:
With derivative action, the controller output is proportional to the rate of change of the measurement from the photodiode. The controller output is calculated by the rate of change of the measurement with time. Derivative action can compensate for a changing measurement.

Thus derivative takes action to inhibit more rapid changes of the measurement than proportional action. When the set point change occurs, the derivative action causes the controller gain to move the wrong way when the measurement gets near the set point. Derivative is used to avoid overshoot.

Hardware implementation tests were performed on samples of concentrate to establish the performance of the closed loop system and response times. Two random set points were chosen to represent the extremes of Brix values that may be specified in the final system. These Brix values were 11.0 Brix (figure 3) and 12.40 Brix (figure 4).

Figure 3, Set point – 11.0
Proportional Band = 300 with no Integral of Derivative Action

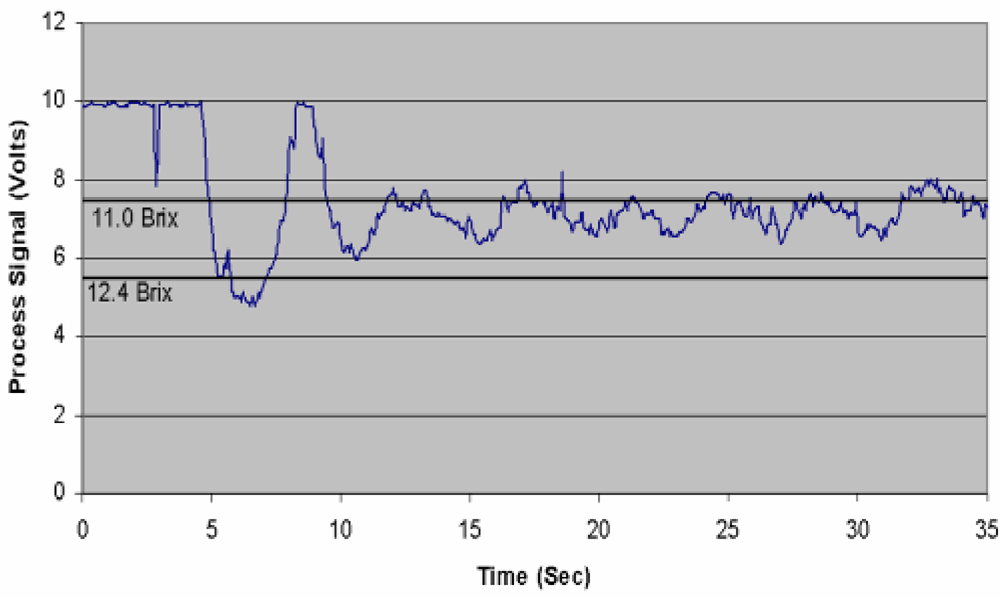
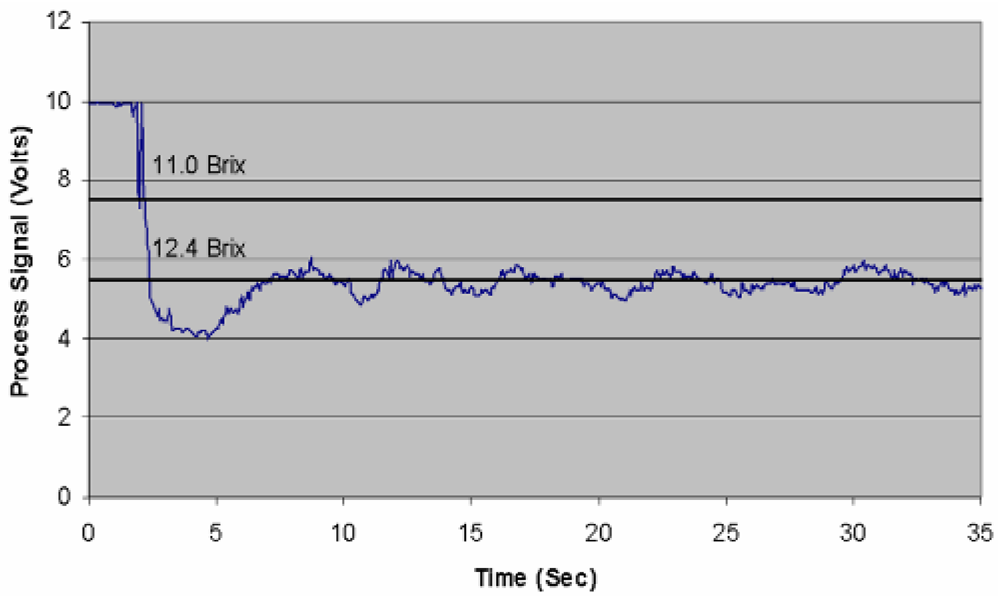


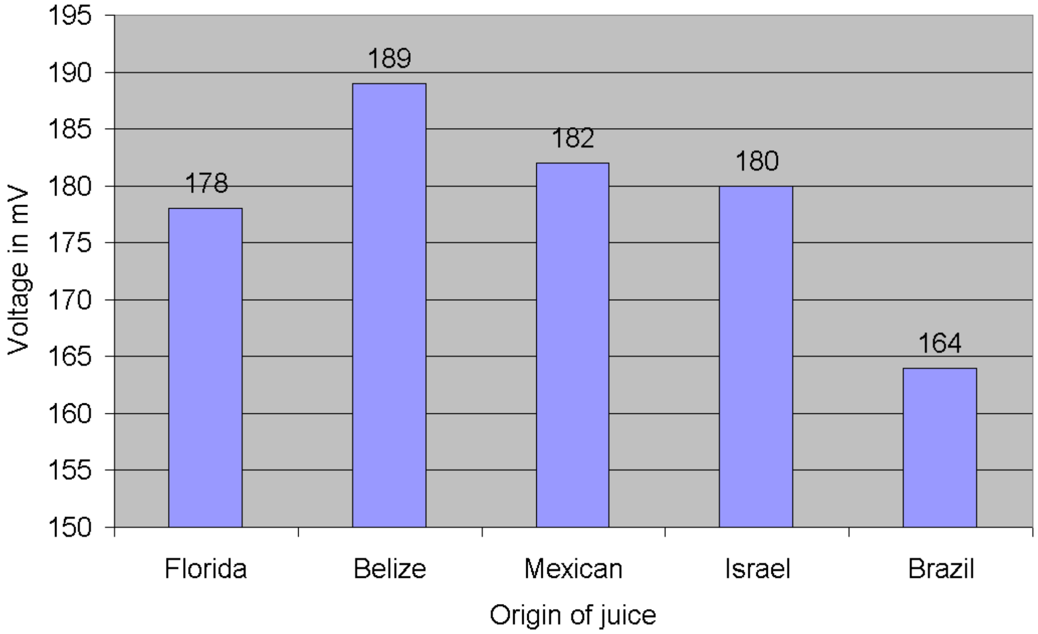
Figure 4, Set point – 12.40
Proportional Band = 150 with no Integral of Derivative Action



Both sets of data show an offset against the set point. These offsets are uniform and average out through the dispensing of a complete drink. When the system is integrated with the final assembly, task 5.1, the slight offset will be reduced.

To establish the repeatability of the system and to attempt to clarify variations, in brand and geographic location, a number of orange concentrate samples were sourced for testing. The tests were performed on all the concentrates reconstituted to a Brix value of 11.80 to ensure that the absorption readings were all relative.

Figure 5. Tests on 5 geographically diverse juices



The results, shown in figure 5, show a variation in light absorption readings of 25 mV for the reconstituted juice. This is roughly equivalent to 0.80 Brix, which is outside the system specified tolerance of +/-0.20 Brix. The variation can be accounted for by the different varieties of oranges used in the manufacture of the concentrate. In order to overcome this variation every brand of concentrate will undergo a simple test to establish the light absorption set point for the recommended brix value. This information will then be built into the product packaging, in the form of a bar code or RFID tag, and read by the dispensing machine.

Work Package 3 – Energy Optimisation

Objectives:

The objectives of this work package were to develop the cooling and heating systems and an adaptive control.

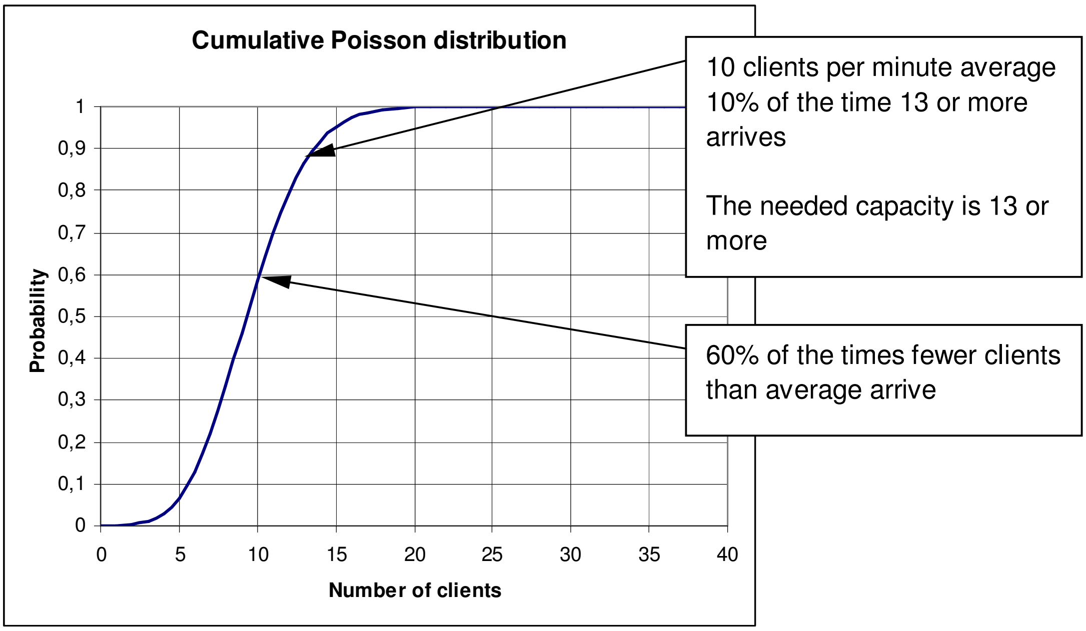
Progress:

The first step in the development of the vending machine was to set up a realistic product specification, from which to base the research and development. With joint effort of the Safevend team the first product specification was defined.

Calculations simulating vending systems and their cooling capacity, followed, which supported the team in specifying a machine with realistic requirements. The following research was used in the developments within all tasks under work package 3.

Poisson distribution:

People entering a canteen or cafeteria will never arrive at regular intervals but this will always be in cluster wise. This cluster wise arrival has a major impact on the build up of queues at the machine. Statistically seen, the arrival of people will correlate to a Poisson distributed curve.



This Graph shows an example in which with an average of 10 clients per minute 60% of the time less clients then average will arrive meaning the machine is idle but 10% of the time 13 or more will arrive creating a queue if the capacity is not sufficient. To prevent long queuing, the capacity of the machine should be in accordance to this meaning the capacity of the machine is to be > 13 persons/minute. As this Safevend vending machine will be used in a canteen type of environment the assumption was made that the arrival of the people would be Poisson distributed and this effect should be taken into account when calculating the needed cooling capacity.

Based on the cooling requirements specified by Autonumis, some preliminary calculations were made with respect to the cooling capacity.

40 W Stirling cooler:
At the start of the project it was the intention to use of a 40 W FPSC fulfilling the requirements of the Safevend machine. A first calculation with this 40 W FPSC with a constant Coefficient of Performance (COP) of 3 was made to see if it could meet the needs. It was assumed that the cold loss from the machine amounted to 10 W. The vending machine was simulated by assuming that there is a queue in front of the machine. New people arrive in the queue according to a Poisson distribution with an average of 300 people per hour. This is equivalent to approximately 60 l drinks server per hour as was requested by Autonumis. People are served by the vending machine. Once a person is served he is removed from the queue. The vending machine only serves drinks if it is able to produce a drink at 5℃. The machine has a cold buffer that allows it to cool water for the drinks and this buffer is filled by the FPSC.

For each individual client, the total waiting time in the queue until he receives a drink has been calculated. The calculation stops once 2400 clients have been served (average 8 hours of vending). Figure 1 shows a typical simulation result.

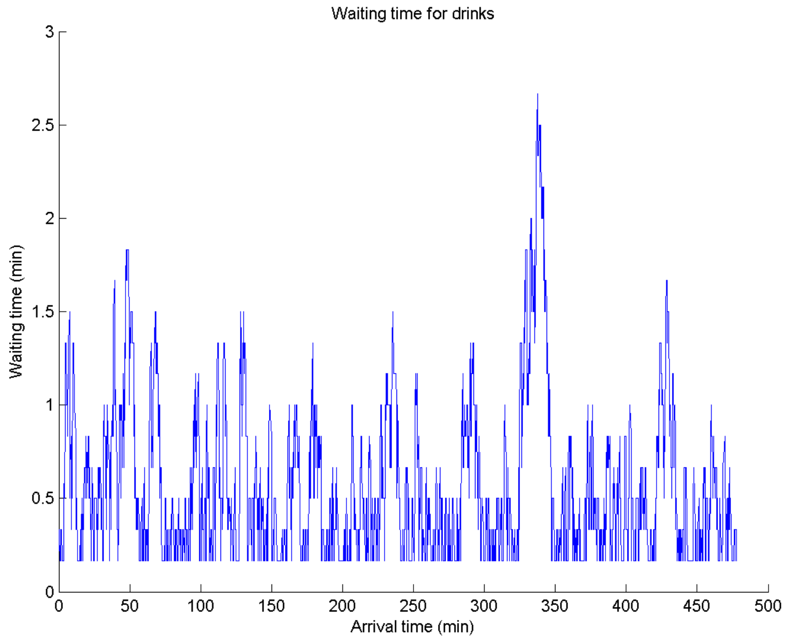


Figure 1 Waiting time as a function of time of arrival at the vending machine for the case where the cold buffer is equivalent to 600 l of cold water

If the cold buffer is equivalent to 600 l of cold water, everyone is served within 3 minutes. The length of the queue determines waiting times. The buffer is never empty.
If the size of the cold buffer is reduced however, the waiting increases drastically once the buffer has become empty. Waiting increased rapidly to several hours for clients that arrived after the buffer had been exhausted.

Moreover, if the buffer is large enough, then the 40 W FPSC still does not have the capacity that is needed to fill the buffer again overnight. The problems with an empty buffer will therefore arise the next day. The only solution is to increase the power of the cooling device.

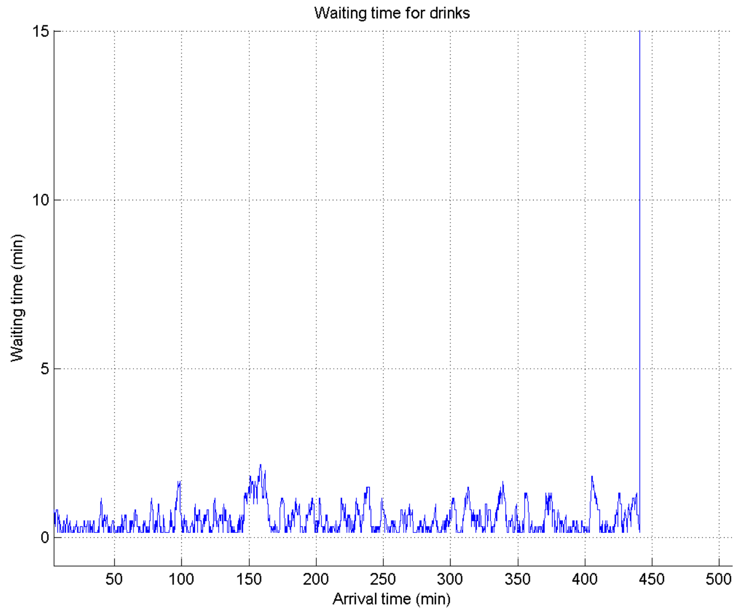


Figure 2 If the buffer is emptied within 8 hours, the last clients have to wait a very long time to be served

Theoretically, the minimum power required by the cooling device can be calculated as the power required to cool 60 l/h during 8 hours (or during the expected operating time per day), divided by 24 hours. The buffer can be used to store cold generated during the hours when there are no clients. Obviously, when the vending machine is designed with the minimum required cooling power, and then the FPSC will operate at full capacity for 24 hours per day.

Following this rule and assuming a COP of 3, the required electrical cooling power is at least 146 W for a machine that is expected to operate for 8 hours every day. The buffer size should then be at least equivalent to storing 320 l of cold water.

Concluding:

1. Buffer sizes tend to become very large if a small FPSC is to be used. One may consider the use of phase change materials to store the cold
2. It is very important for the design of the vending machine to define not only the capacity of the machine, but also the expected operating time per day.
3. When the time for serving 1 drink is 10 s, waiting times can already accumulate to 3 minutes. Therefore the time needed to prepare a drink should certainly not be more then 10 s. if one aims at a capacity of 60 l/h.

Cooling capacity and buffer size:
Suppose the demand 60L/hour as is in the spec. This would mean 300 clients per hour.

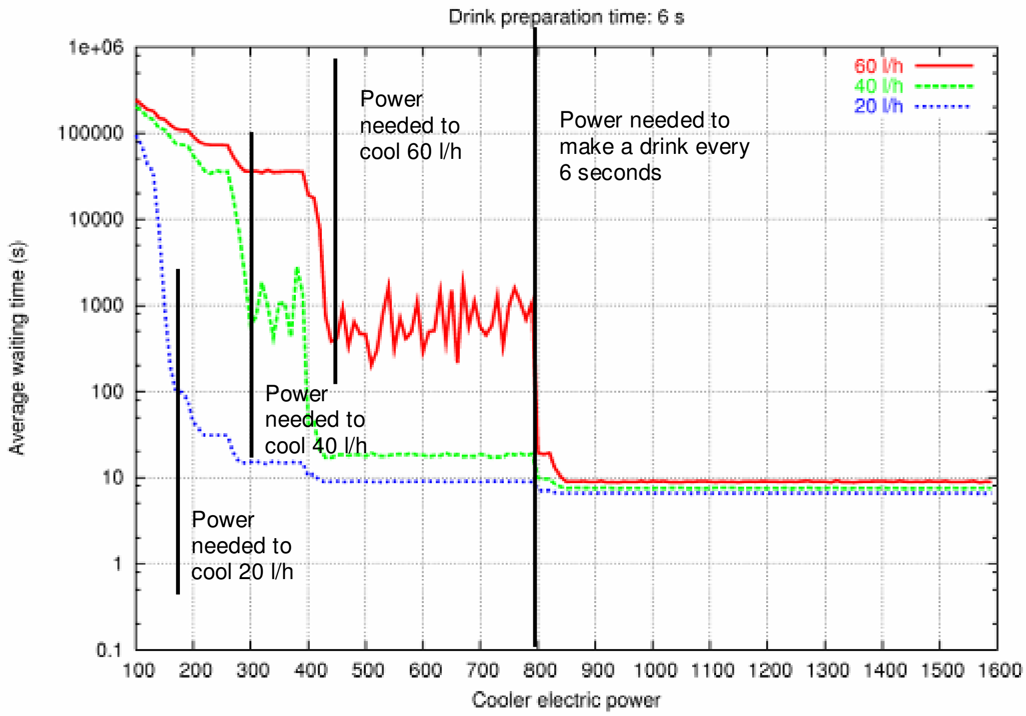
This means at average 1 drink every 12 sec. With preparation time of 12 sec no queuing if each 12 seconds client would arrive to take the drink. According to the Poisson distributed arrival of clients however the average waiting time will build up to 500 sec (> 8 minutes)

Conclusion:
Drink preparation time is a crucial design factor of the machine.
In principle there are two different methods to calculate the needed cooling capacity:

Average demand based. This will give the absolute minimum required cooling power. No queue etc. taken into account
Based on preparation speed. This will give the absolute maximum cooling capacity needed when continuously preparing drinks at preparation speed.

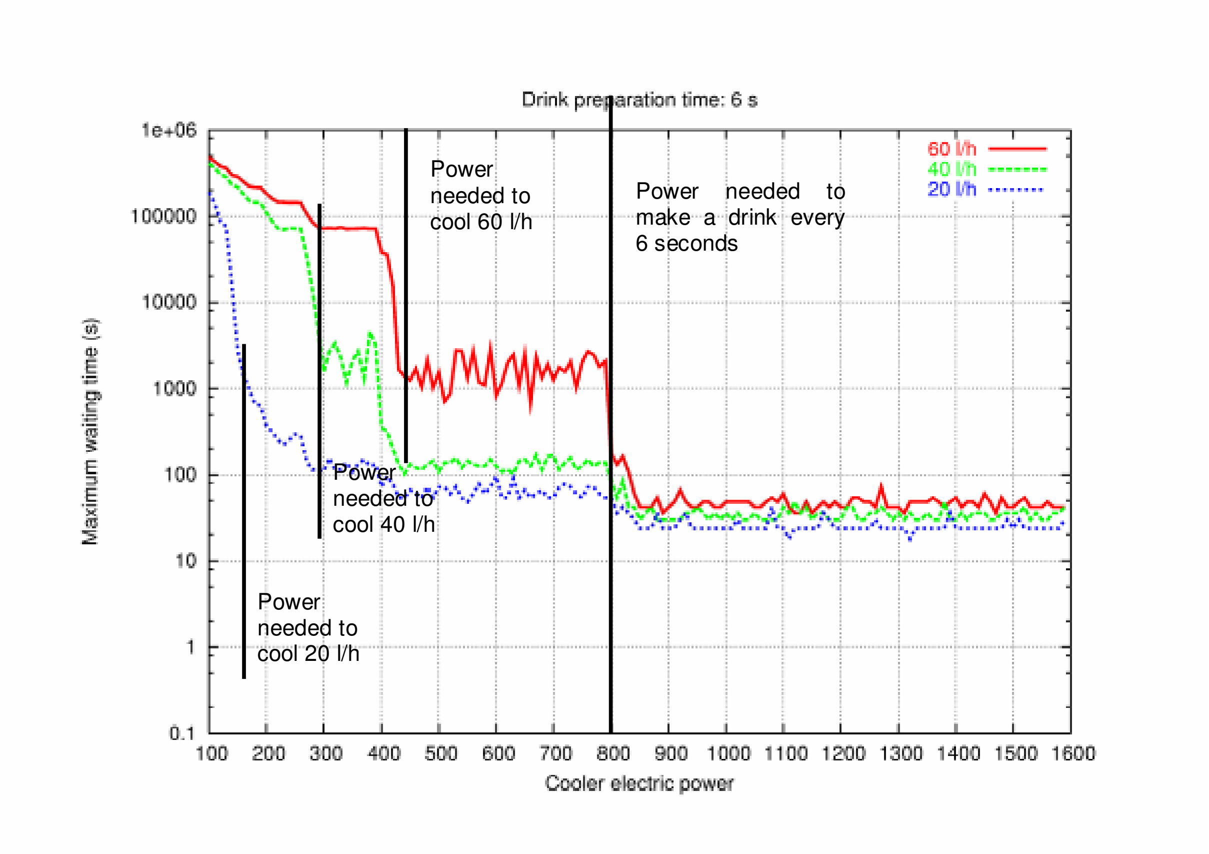
The required cooling capacity based on preparation speed is always higher than the required cooling capacity based on average demand. One may however still decide to build a machine with a cooling capacity based on average demand by introducing a buffer.
Thus one may choose any cooling capacity between maximum and minimum provided that one also selects an appropriate buffer.

Average waiting time:
Based on a fixed preparation time of 6 seconds. Three graphs are plotted for 20, 40 and 60 L/hour showing the relation between average waiting time and the required electrical cooling power. The vertical lines show the power needed to cool the required litres per hour.



Maximum waiting time:

Based on a set preparation time of 6 seconds. Three graphs are plotted for 20, 40 and 60 L/hour showing the relation between maximum waiting time and the required electrical cooling power. The vertical lines show the power needed to cool the required litters per hour.



So far for both situations no cold buffers were taken into account.

Design parameters for cooling system:
With this knowledge new calculations were made with the following criteria: The maximum queue based on a poison distribution may never be more than six persons. If the queue is longer, people will simply decide to go elsewhere. This means the maximum waiting time is 7 times the preparation time. For practical reasons, only 300, 200 and 100 clients per hour were considered.

If the machine is build with the minimum cooling power installed, then it can only achieve the required drink preparation time if it has a sufficiently large buffer. The required buffer size for this scenario was estimated.

Drink preparation time	Capacity (clients per hour)	Min cooler power (W) Elec. COP 3	Max cooler power (W) Elec. COP 3	Estimated maximum buffer (e.g. L cold water)
12 s	100 (20 l)	150	450	5
10 s	100	150	540	5
6 s	200 (40 l)	300	800	6
50 s	26 (5 l)	40	108	8
135 s	12 (2 l)	19	40	7

Best-suited configuration seems at this stage:
Preparation time of 6 seconds, capacity for 200 clients per hour, needed minimum cooling power of 300 W with COP of 3, water or e.g. buffer of 6 litres, maximum waiting time always less then 42 sec. (Poisson distributed)

Obviously, there may be other factors affecting the drink preparation time, such as the Brix measurement or the time needed to mix the drink properly. If it proves to be impossible to prepare a drink in 6 seconds, then this means that either the capacity will be less then 40 l/h average or one must accept longer queues than 6.

Preliminary Design Of A Conventional Cooling System:

Using the knowledge obtained from the calculations discussed above, a preliminary design of a conventional cooling system was made. This design can act as a guideline for the desired performance of e.g. a Stirling cooler or an improved compressor-based cooling system. The boundary conditions for the design are summarized in Table 1.

Table 1 Boundary conditions for the design

Parameter	**Condition**
Capacity	Average: preferably 300 clients per hour. However, less is acceptable Peak: 60 l/h should be supplied continuously during a least 10 min.
Water temperatures	Tap water temperature may be assumed to be 15°C. Calculations for a tap water temperature of 24°C will be made to evaluate the worst case scenario Drink temperature will be 5°C. However, to allow for a warm container of concentrate, the water must be cooled to 3°C.
Buffer sizes	A buffer size of maximal the equivalent of 10 l. of cold water is deemed to be acceptable.
Compressor choice	A commercially available compressor of the range of Electrolux must be selected. The cooling is assumed to be static. The compressor will be selected on the basis of the maximum COP for the required capacity. On the basis of foregoing calculations, the compressor cooling capacity must be in the range 450 – 1500 W.

Based on these boundary conditions, the following compressor was selected: GQY90AA_b. This compressor provides a cooling capacity of 479 W with a COP of 1.97. The power consumption is 243 W and the mass flow of refrigerant is 9.4 kg/h. The refrigerant type is R-134a.

Given, this compressor, the buffer size can be determined. Two considerations are important for selecting the buffer size: the average capacity and the peak demand. The buffer requirement for the peak demand can be calculated as follows. The volume flow of cold water (Q) supplied by the cooler is given as function of he cooling power (P_c) by

$$Q = \frac{P_c}{\rho c_p \Delta T}$$

In the base case, the temperature difference is 12°C. Using the properties of water for the other parameter, one obtains: Q = 34 l/h.

If the vending machine must supply 60 l/h, then 26 l/h is drawn from the buffer. The machine must be able to comply at least 10 minutes. Thus, the buffer size must be at least 4.5 l.

In order to achieve an average capacity of 300 clients per hour, the buffer size must be at least 60 l (calculated using queuing theory). This is unacceptably large.

A buffer size of 6.5 l results in an average capacity of 220 clients per hour.
This buffer will supply a continuous flow of 60 l/h during 15 minutes.

In the worst case, the tap water temperature will be 24°C. In that case, the temperature difference is 21°C. The volume flow cold water supplied by the cooler is then Q=19 l/h.

The buffer is required to supply 41 l/h for the maximum demand of 60 l/h.

The machine can comply for at most 9 minutes.

The average capacity is 120 clients per hour.

The best compromise is reached with a buffer size of 6.5 l.

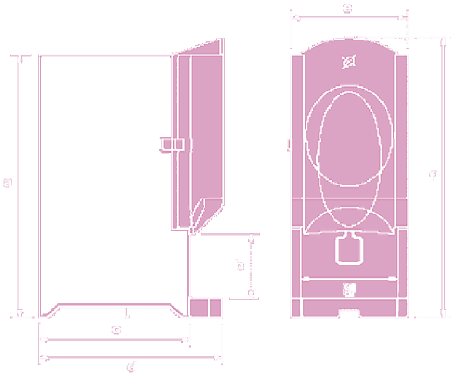
The preliminary design is therefore a conventional cooling system with compressor GQY90AA_b and a buffer of 6.5 l cold water.

Task 3.1 Stirling Cooler Developments
Task Leader Partner 4 - GLOBAL COOLING

Objectives:
The design and manufacture of a prototype FPSC (Free Piston Stirling Cooler) rig.

Progress:
The approach to the FPSC cooler development was too construct an ambient temperature controlling test rig and monitor the input power and performance of a dual drink dispenser cooled by a conventional cycle compressor then modify this unit to be cooled by a FPSC and compare the performance of the two units. A parallel activity is to access the cabinet for efficiency.

Test Rig:
The design and manufacture of the FPSC ambient test rig was conceived around the testing of the drinks vending machine model NT. This is a dual bag in box vending machine, the NT model, which currently utilizes an Electrolux compressor. The dimensional information for this machine and similar models in the range can be seen in figure 1.



MACHINE		BOX SIZE			MACHINE
Model	Description	w	d	h	WEIGHT
NB	10 litre box	120	255	420	32 kg
NG	10 litre box/basket	200	197	325	30 kg
NN	10 litre box/basket	165	255	400	35 kg
NU	3 UK gallon (13.6 litre) box	258	230	285	38 kg
NS	20 litre box	250	255	380	40 kg
NT	2x10 litre box/basket	2 x135	2x315	2x400	40 kg

< Selected machine

Figure 1. Drinks Machine Dimensional information from www.autonumis.com

The test rig consisted of an environmental test chamber which was held at a constant 31Deg C as per the Coca Cola ™ drinks machine ambient temperature test specification. The requirement to test from 10deg C was removed, as this would not represent the worst-case conditions for the cooling device. Instead the Coca Cola™ test standard was adopted. This was done using a circulating fan and heating element connected to a Proportional Integral Derivative (PID) temperature controller. A schematic of this arrangement can be seen in Figure 2.

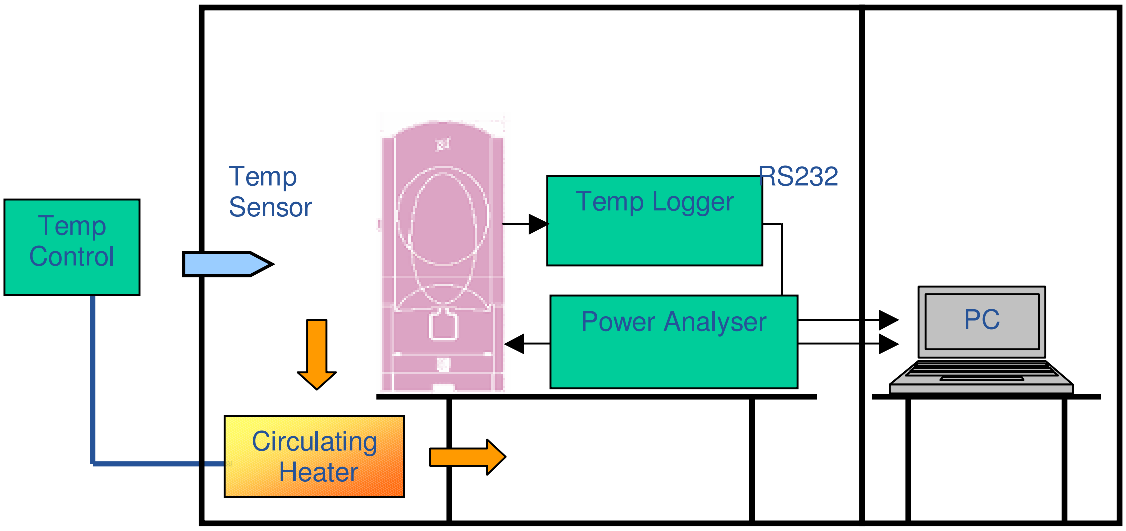


Figure 2 - Ambient Test Rig Schematic

The design of the chamber temperature control system was based around a PID temperature controller. This controller sensed the temperature from a ‘T’ type thermocouple and its output was connected via a relay to a re-circulating fan heater. The schematic for this control system can be seen in figure 3.

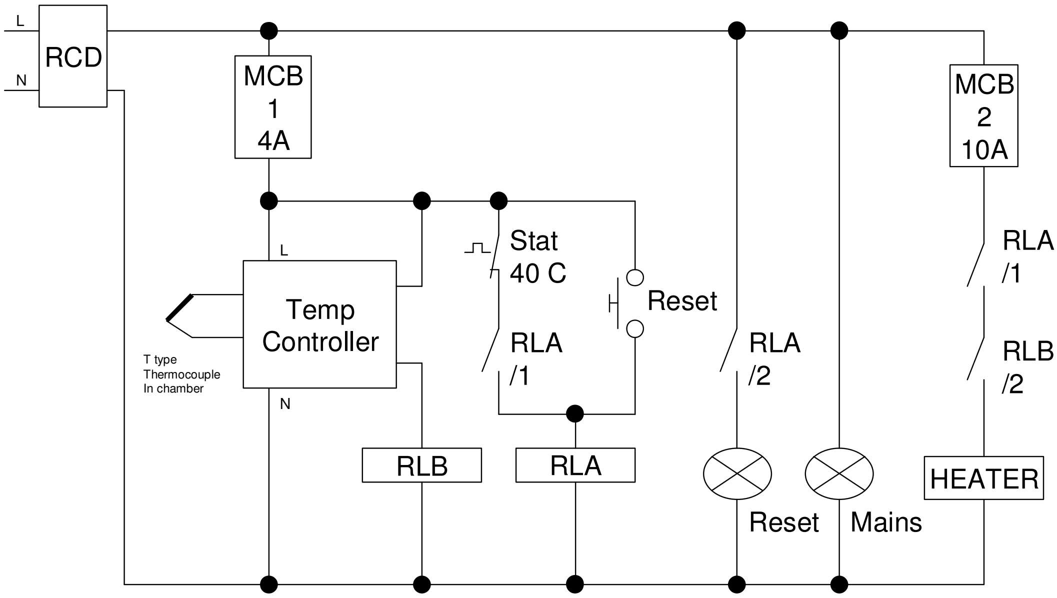


Figure 3. Control System Layout

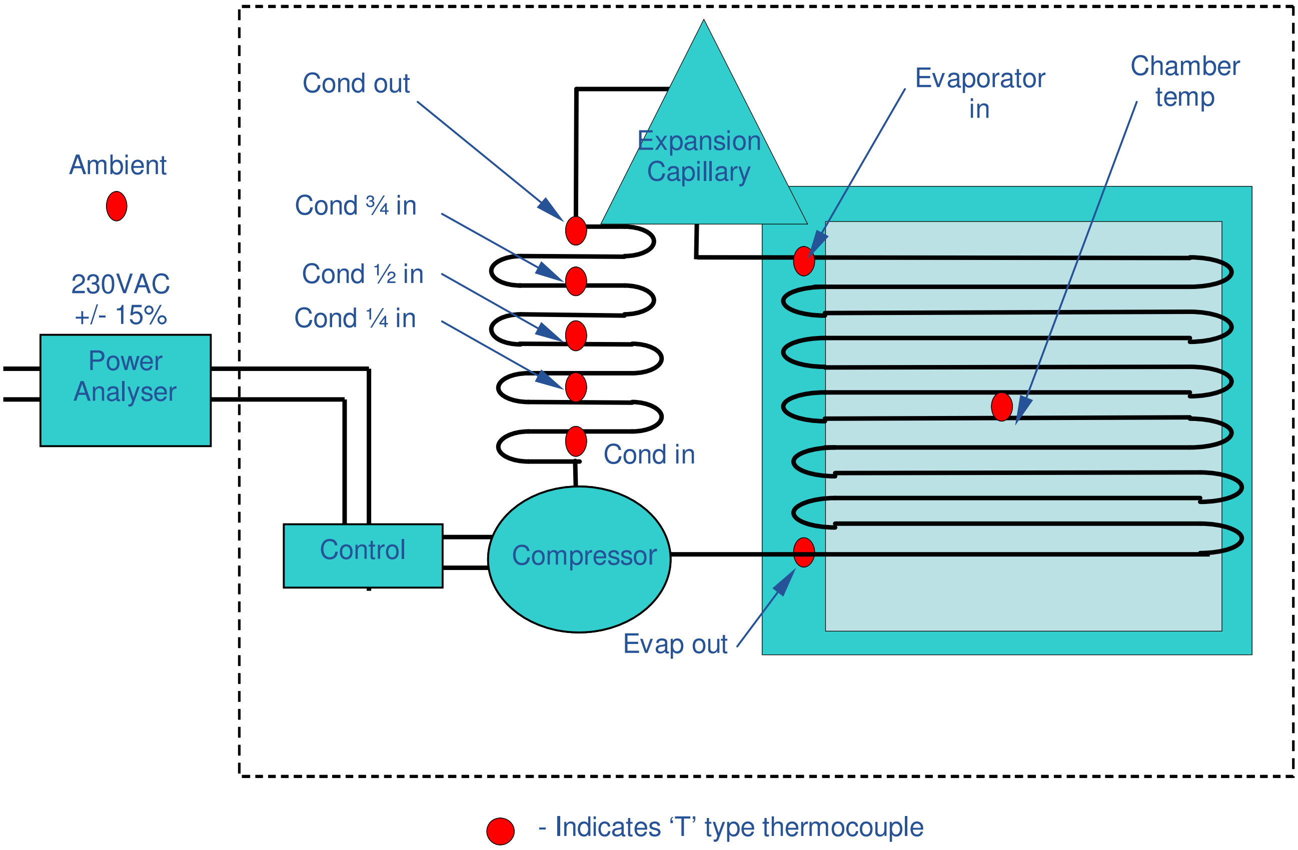


Figure 4. Positions of Temperature Sensors

The rig was constructed as per the schematics shown in figures 2, 3 and 4. An Image of this rig can be seen below in Figure 5, which shows the dispensing unit supplied by Autonumis and the data logging equipment.

Figure 5. Photographs of Machine in Test rig unit

Results:

Tests were conducted at 25ºC and 50% relative humidity. The unit was ran for a continuous 6 hour period and the logging of all temperatures shown in figure 4 and the power factor, power consumed, applied voltage and current were also logged at 2 second intervals.

The tests were repeated for no load, 25 and 40-watt load. This was done using lamps of the appropriate sizes.

Thermal Images of Cabinet:

Thermal images of Cabinet after a 3 hour soak at a 2 Deg C set point in an ambient of 25 Deg C

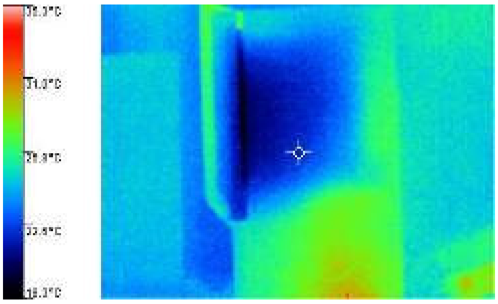


Figure 6. Thermal image of RHS, showing heat leak.

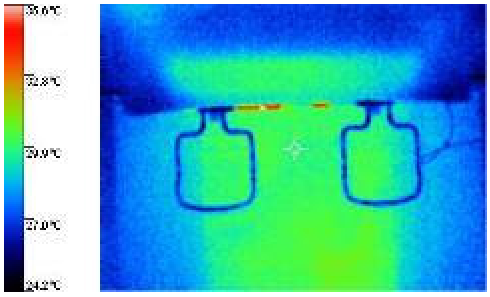


Figure 7. Thermal image of front, showing heat leak.

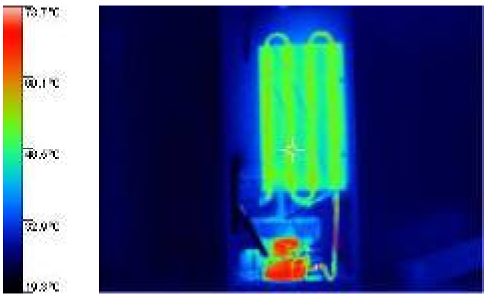


Figure 8. Thermal image of the rear, showing heat leak.

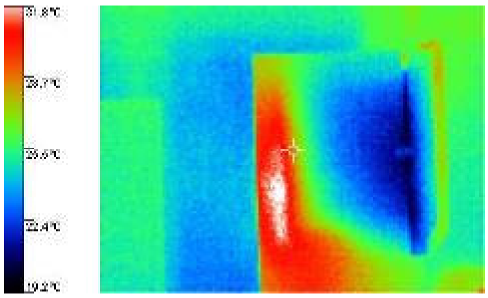


Figure 9. Thermal image of LHS of showing leakage and compressor heat

Rankine Compressor Test Results

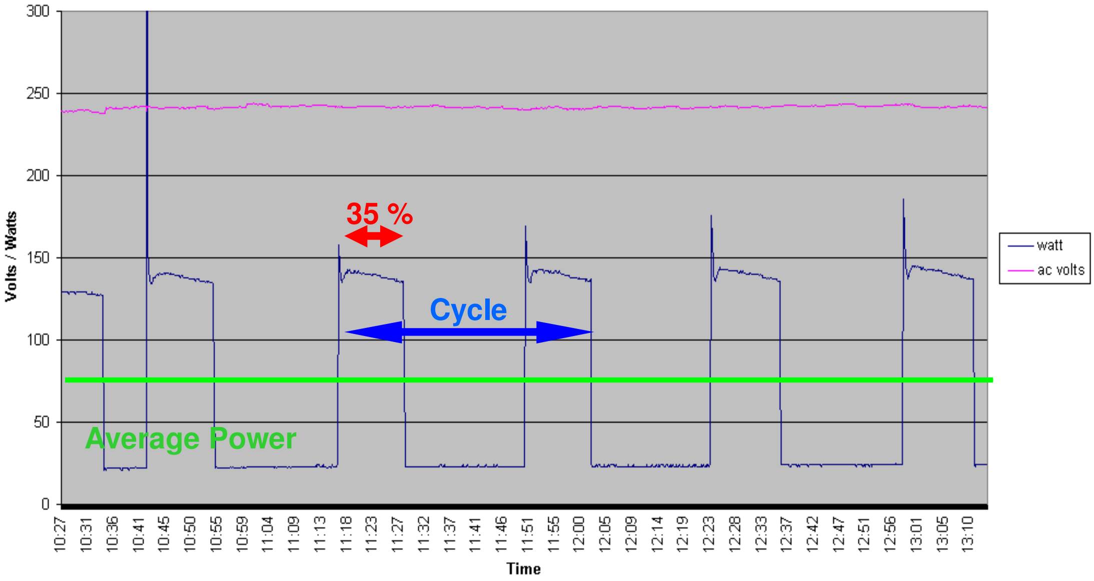
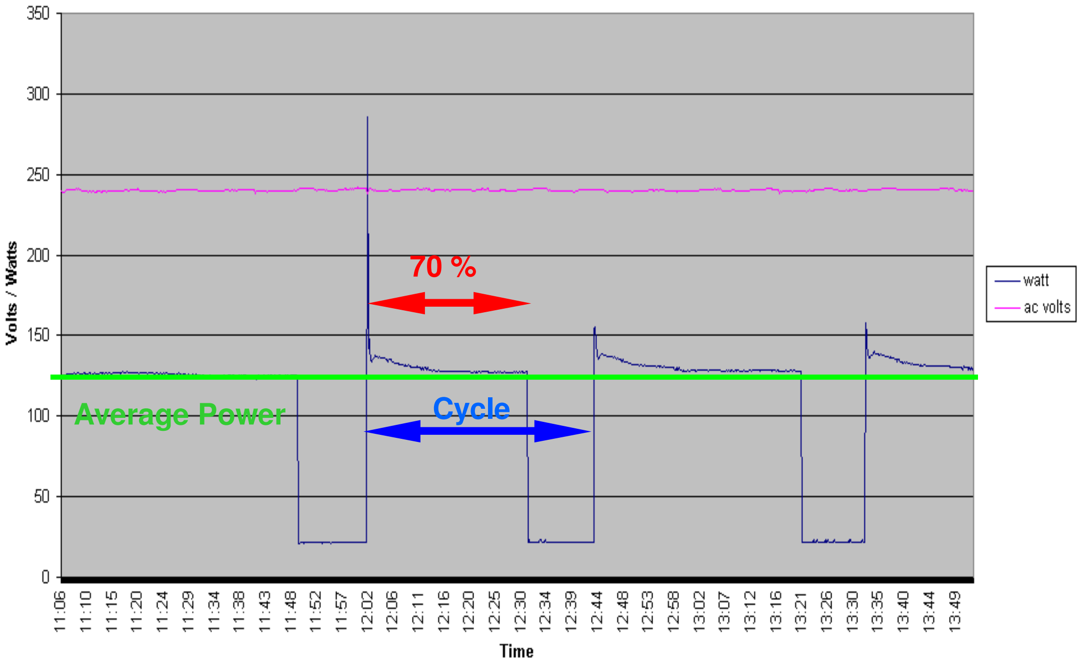
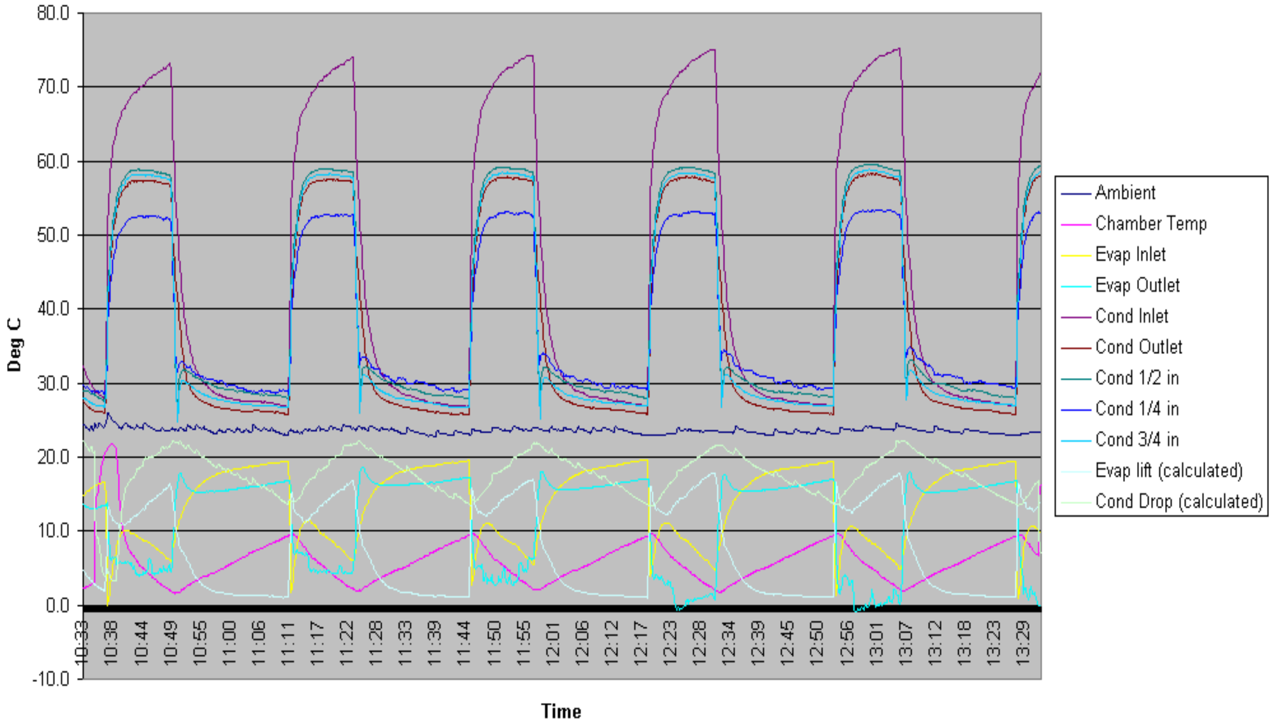
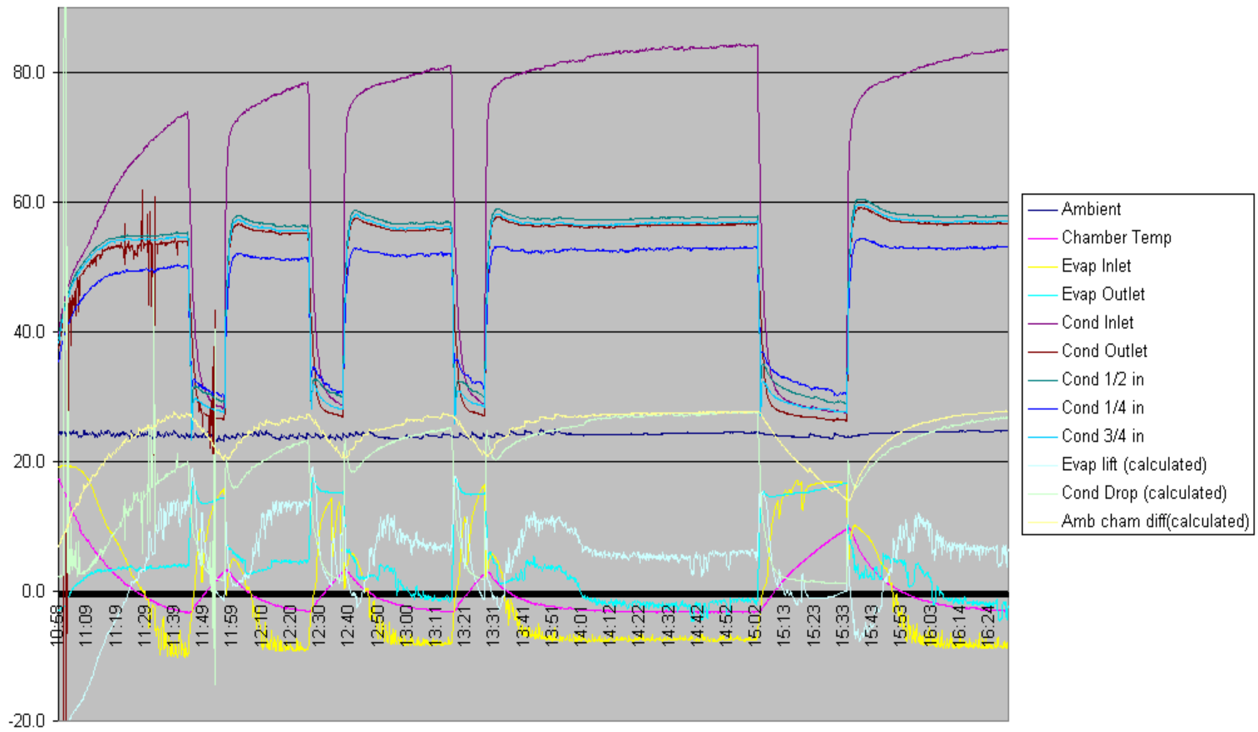


Figure 10. Rankine Test results (Power) –**set point 8 deg** ambient 25 deg




Deg C
Time
Ambient
Chamber Temp
Evap Inlet
Evap Outlet
Cond Inlet
Cond Outlet
Cond 1/2 in
Cond 1/4 in
Cond 3/4 in
Evap lift (calculated)
Cond Drop (calculated)


Ambient
Chamber Temp
Evap Inlet
Evap Outlet
Cond Inlet
Cond Outlet
Cond 1/2 in
Cond 1/4 in
Cond 3/4 in
Evap lift (calculated)
Cond Drop (calculated)
Amb cham diff(calculated)

Heat Load Test Results of Chamber

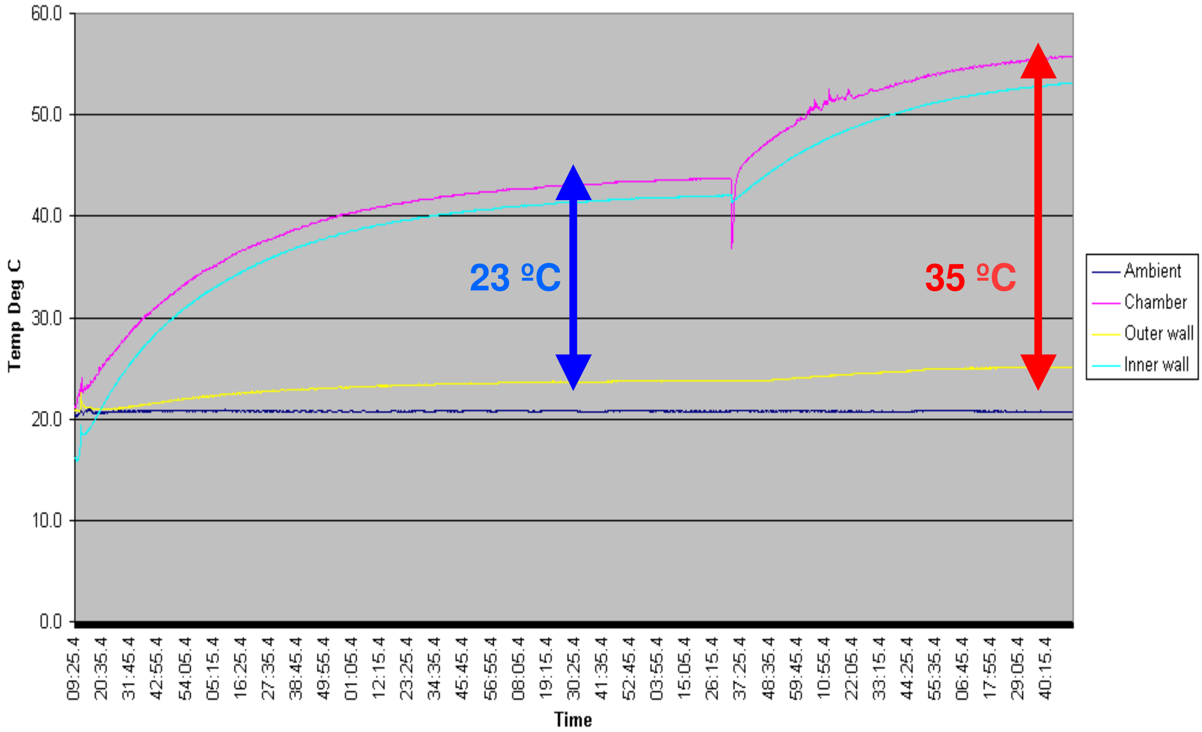


Figure 14. Heat soak test 25 and 40-watt load at 26 °C ambient

Figure 15. Chamber with heat load in place, which gave results as per fig.14

Free Piston Stirling Cooler (FPSC)

The FPSC unit has been integrated with the control electronics and tested as a stand-alone unit, as shown in fig 16. The cooler performs particularly well, giving an extremely quick and precise cooling performance. An interface, between the FPSC system and the cooling cabinet will now be designed. Now the baseline data has been established the FPSC will be installed and tested. The resulting data will be used to establish performance gains.

Conclusions / Discussion Points

- Chamber set point is between 2 deg C and 8 Deg.
- When on a 2ºC set point, chamber temp can drop to -3ºC. This indicates a large negative hysterisis on the control stat.
- Duty cycle of compressor increases with lower temperature, as expected. **70% duty at 2ºC** set point and **35% Duty at 8ºC** set point with an ambient of 25ºC.
- Temperature reading on unit control stat reads does not seem accurate (reads high by 4ºC).
- Rankine cycle tests conducted at 31ºC caused the compressor to over heat and trip out.
- Tests were also conducted at 5ºC and 10ºC set points.

General Chamber Comments

- Thermal images show poor thermal break on chamber sides and seal.
- Heat load tests give an appliance constant of **1.1 W/ºC at 25 watt** and **1.2 W/ºC at 40 watt load**.

Task 3.2: Heating and Cooling Energy Transfer Development
Task Leader: Partner 4 - GLOBAL COOLING

Objectives:
To design and build an experimental test rig to evaluate energy exchange designs.

Progress:
In order to test the Free Piston Stirling Cooler (FPSC), within the test rig developed in task 3.1, an efficient means of transferring the cold energy form the FPSC unit to the dispensing cabinet had to be developed and manufactured.

As the FPSC is a closed unit, a separate cooling circuit had to be developed to transfer the cold energy. The diagram below shows the CAD model of the dispensing cabinet, including a cooling circuit and FPSC unit. A thermosyphon was chosen as the means to connect the FPSC unit to the cold space.

The thermosyphon is fabricated from micro bore copper tubing. The condenser consists of a number of wraps of the tubing around the cold head of the FPSC while the evaporator consists of a few wraps of the tubing around the walls of the cold cavity.

The thermosyphon is a two-phase system using CO_2 in both a liquid and vapor form. It consists of an evaporator section and a condenser section and is driven by gravity. CO_2 is used as the heat transfer medium within the thermosyphon. The condenser, on the FPSC unit, cools the CO_2, which then becomes a liquid, travels down the thermosyphon and into the evaporator, where the cold energy is exchanged. This forces a phase change in the CO_2, from a liquid into a vapor, in turn the CO_2 becomes lighter and travels up the thermosyphon and returns to the condenser where the cycle begins again.

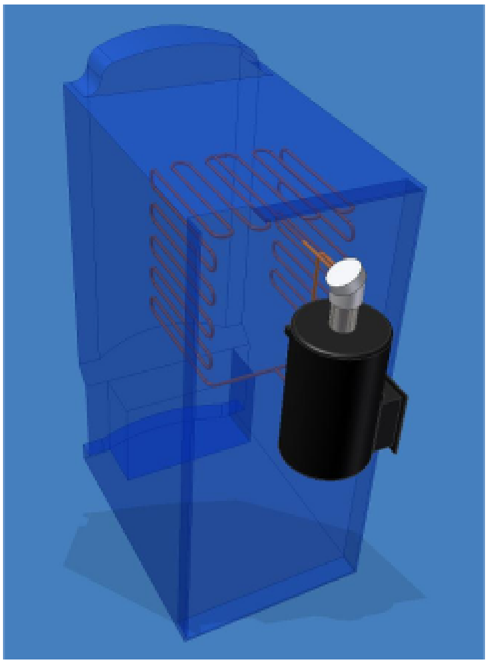


Figure 1

The CAD image shows the position of the thermosyphon within the dispensing cabinet and the FPSC unit.

As the thermosyphon is gravity fed the condenser must be located above the thermosyphon.

In order to efficiently connect the thermosyphon to the cold head on the FPSC unit and adaptor had to be manufactured. This consists of an aluminium cap, which is bonded to the cold head, and a copper condenser fixed to the cap. The thermosyphon inlets and outlet are then brazed into the copper condenser.

Figure 2. Assembly drawing of the condenser:

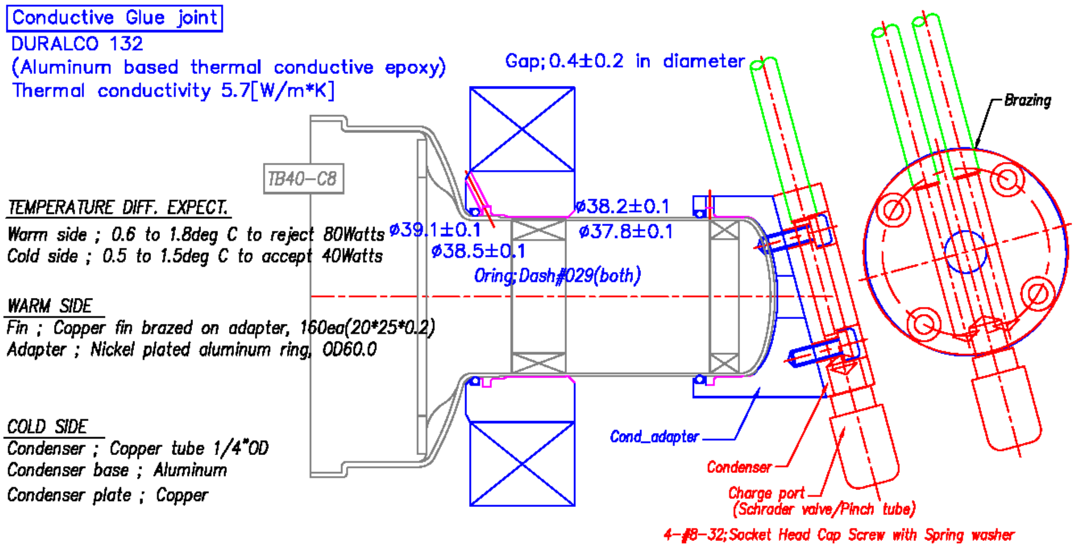


Figure 3 and 4 show the FPSC unit with the condenser fixed in position; this is bonded to the cold head with an Aluminium based thermally conductive epoxy. The condenser also includes a Schrader valve, which is used to charge the circuit with CO_2.

Figure 3

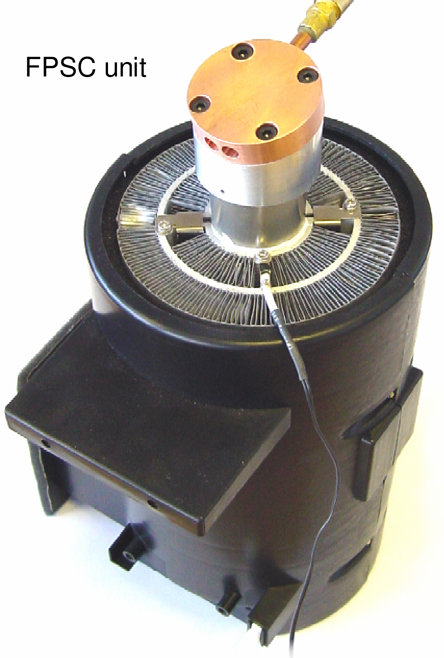
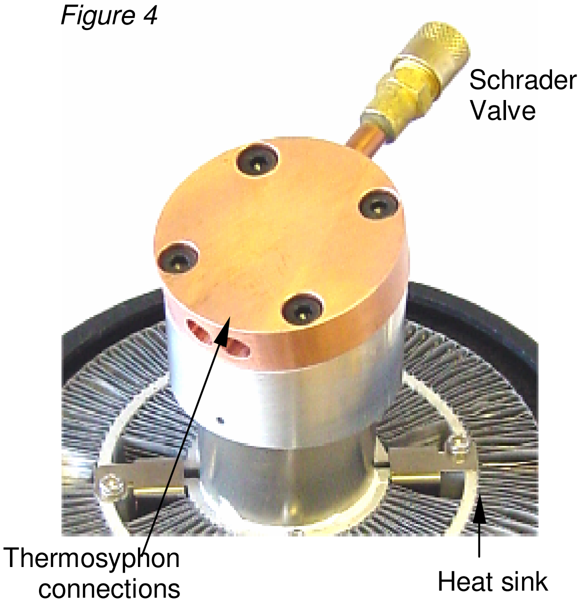
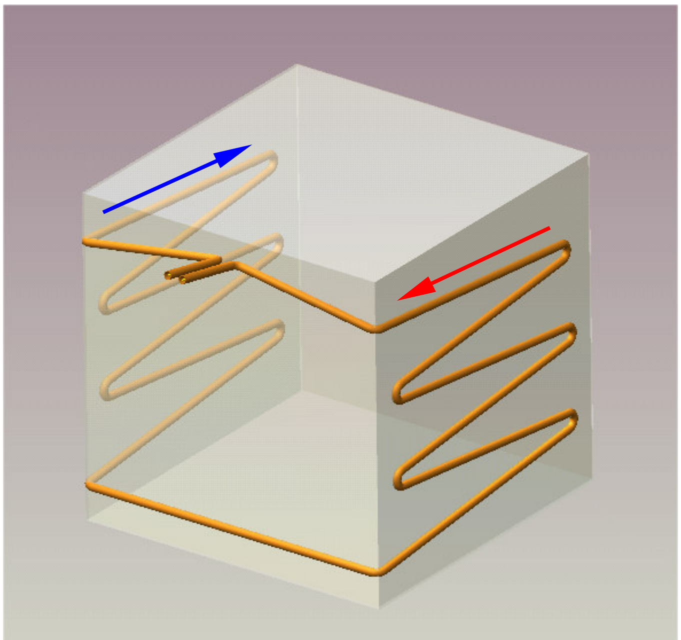


Figure 4



Through the development of the design the configuration of the thermosyphon changed to a simpler form as shown in figure 5. The blue arrow shows the direction of the CO_2 liquid and the red arrow shows the returning CO_2 vapour.

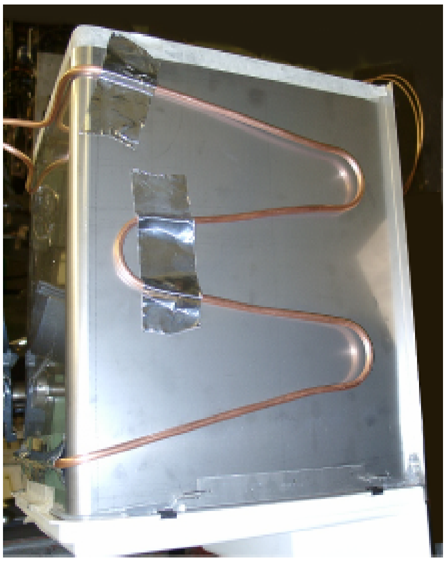
Figure 5



The images below, figure 6 and 7, show the FPSC unit mounted to the rear of the dispensing machine and the thermosyphon being fabricated for this machine and fixed to the external cooling surfaces of the cabinet.

Figure 6

Figure 7



The following graphs (figures, 8 and 9) show the test data results for the FPSC compared against the Rankine compressor. Both cooling systems were tested on identical Autonumis NT machines, with equal loads of two 10-litre bags of concentrate. The units were tested at the same time and within the ambient temperature controlling test rig and monitoring systems, developed in task 3.1, to ensure a fair test.

The graph below, figure 8, depicts the initial pull down test, whereby both machines were loaded with 20 litres of concentrate. The concentrate had been stored at an ambient temperature of 25ºC and the cooling systems were set to pull the temperature down to 15ºC.

Figure 8. FPSC versus Rankine – Juice pull down to 15ºC from 25ºC (Ambient 25ºC)

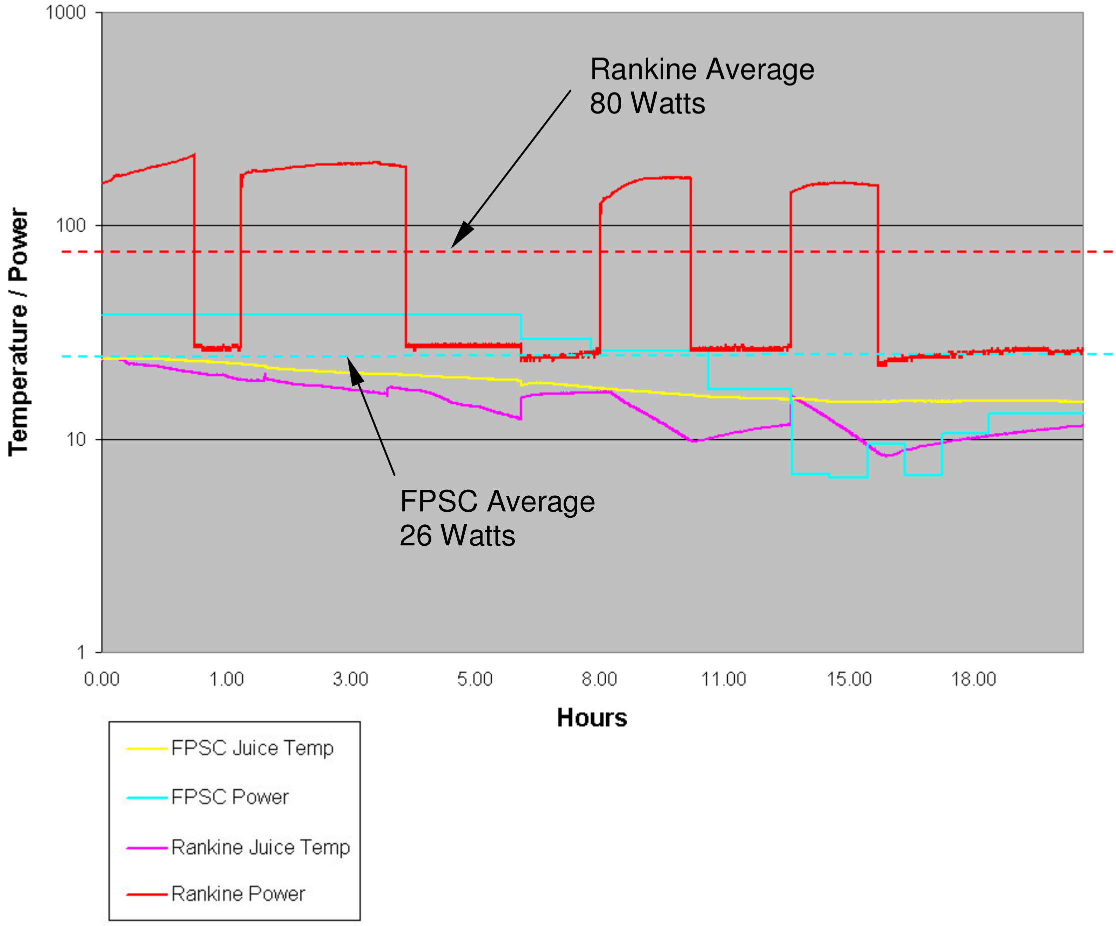
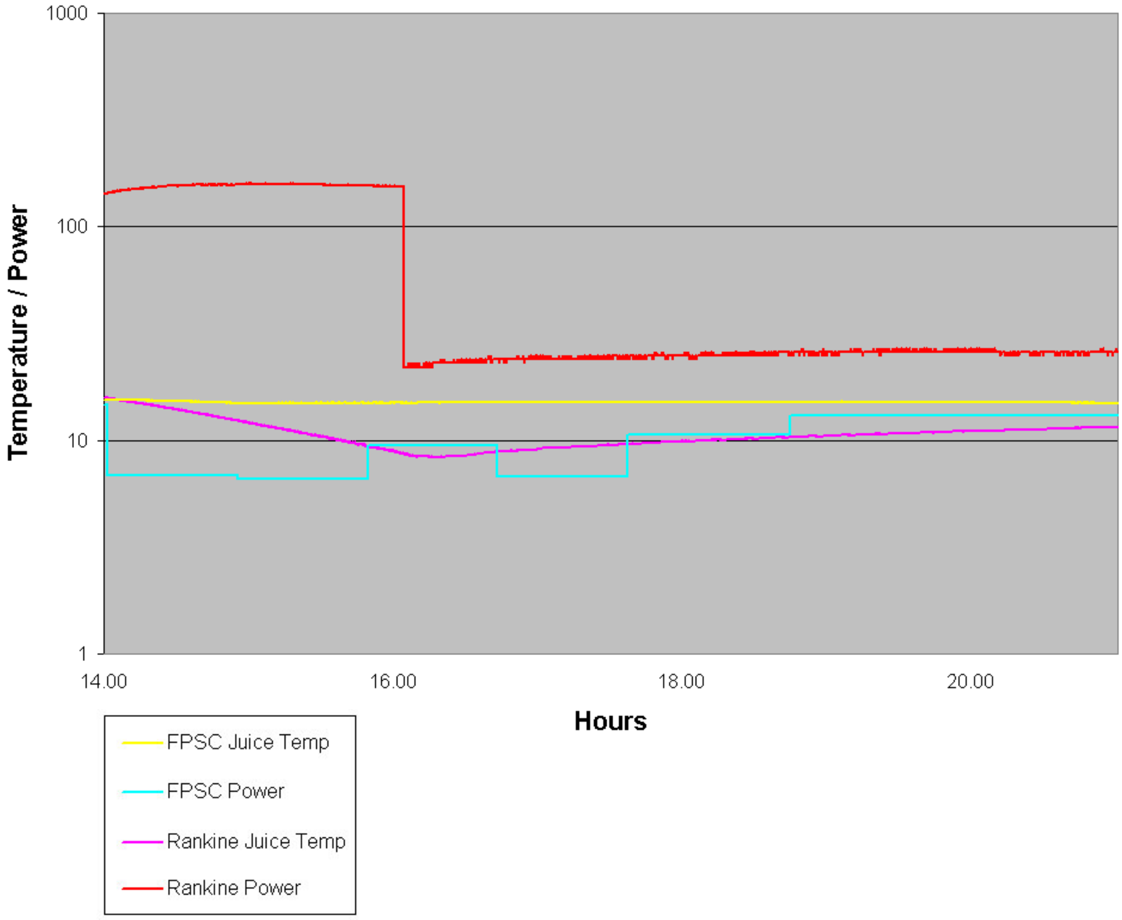


Figure 9, below, illustrates the power consumption required to maintain the juice at 15ºC. This diagram shows the considerable improvement in efficiency of the FPSC unit over the Rankine compressor. The FPSC unit, when settled, uses a constant 13 watts. Compared to the Rankine unit, which is constantly cycling on and off, using an average of 44 watts.

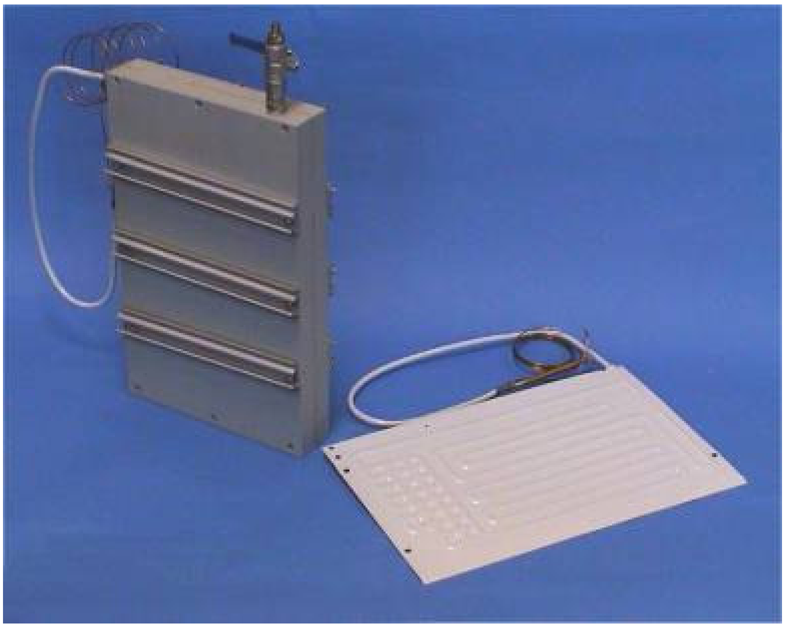
Figure 9. FPSC versus Rankine – Maintaining Juice at 15ºC (Ambient 25ºC)



Conclusion:
In the pull down test the FPSC did suffer because of its limited capacity, as this is an emerging technology a full range of devices are not yet available, larger capacity FPSC will be available shortly. The real benefit of the FPSC unit can be seen when maintaining the juice at a specific temperature, the improved performance and modulatory nature of the FPSC unit meant that it consumed considerably less power that the Rankine unit. The FPSC unit also maintained the cabinet and juice and a more accurate temperature, unlike the Rankine unit, which has a broad temperature range and cycles the compressor on and off.

To complement the cabinet, which cools the concentrate, prior to dispensing, it was felt that it would be necessary to cool the incoming water. As the ratio of water to concentrate is 5+1 (5 parts water to 1 part concentrate) variations in the temperature of the incoming water would have a great influence on the end temperature of the drink.

The design of the unit took the form of a 6-litre buffer, which would continuously chill the water. It was agreed to chill the concentrate to15ºC and estimated that to deliver a drink to 6ºC then the buffer would have to cool the incoming water to a temperature of 4.2ºC. The picture below shows the cooler prototype, this consists of an evaporator, which would be enclosed in a fabrication. The water would then be circulated form one side of the evaporator to the other as required.



Tests are currently being performed on the buffer; the results will be available in the next quarter.

Task 3.3 Steam Generation Unit Design
Task Leader - Partner 4 – GLOBAL COOLING

Objectives:
Design and manufacture of a steam generation test rig.

Progress:
Based on the cleaning recommendations from WP 1.4, a steam sterilisation concept was developed. This concept consists of two cleaning phases, as shown in figure 1:

1. Rinsing with hot water (90℃) to remove all visible contamination
2. Heating with overheated steam (110℃, 1 bar) to dry and sterilize all surfaces in the unit. The required heating time is to be determined from challenge tests.

The generator will be connected to the juice-inlet using a three-way valve, see figure 2.

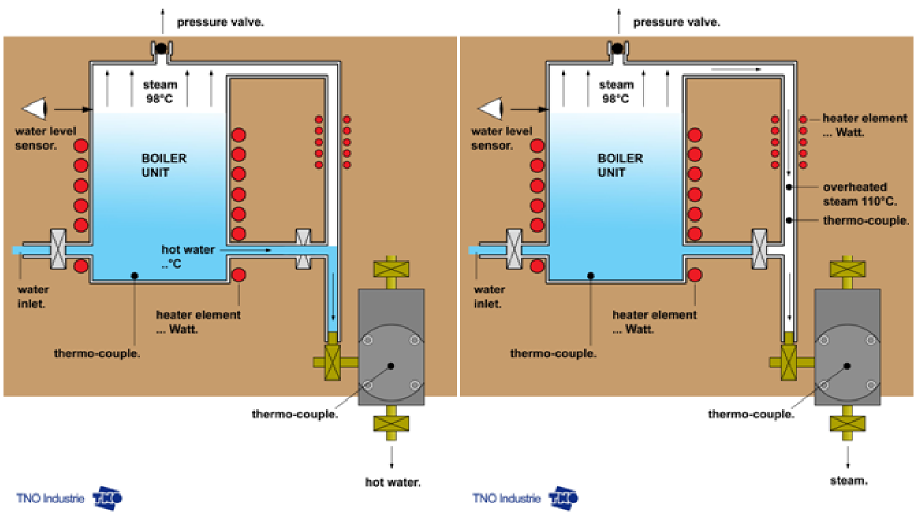


Figure 1. Cleaning phases

The cleaning sequence proceeds as follows. The generator is filled with water that is heated to 90℃. Once the water reaches the desired temperature, a valve is opened to rinse the unit (left image). The water level is monitored and maintained within predefined bounds. After a fixed period, the valve is closed and the steam is opened (right image). Steam is produced at a constant rate by controlling the heating power. The steam flow is maintained until the surface of the unit reaches a temperature of 110℃.

A steam generator was designed that is capable to deliver sufficient amounts of hot water and steam. The generator consists of a vessel; heated by electric elements, figure 3. The generator and a test rig are now being built. The cleaning and sterilising capabilities of the generators will be tested in a set-up as described in WP 1.4

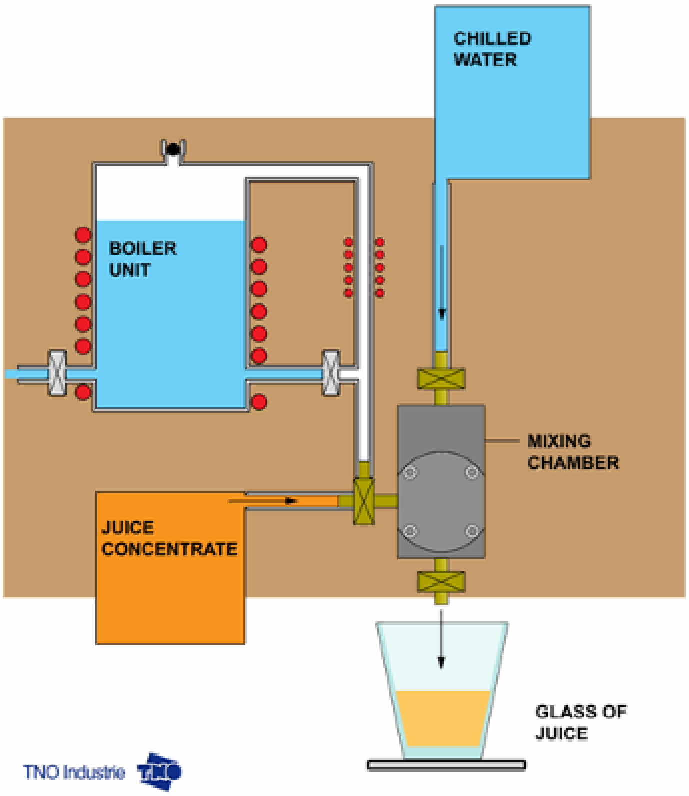


Figure 2. Steam generator connected to the juice inlet of the mixing unit

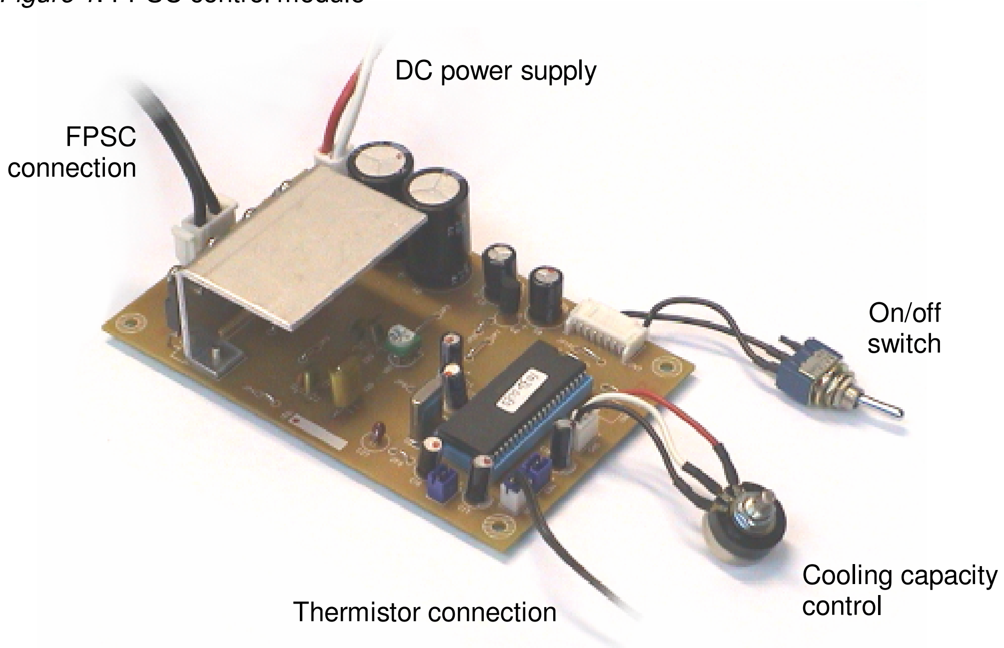
Figure 3. A prototype of the steam generator

Task 3.4: Adaptive Control Energy Monitoring
Task Leader: Partner 4 - GLOBAL COOLING

Objectives:
Development of adaptive control temperature and system usage monitoring control electronics.

Progress:
In order to test the FPSC system temperature control electronics had to be incorporated. The FPSC electronics module, figure 1, controls the operation on a modularity basis, so to prevent start/stop operation of the FPSC and maintain a precise juice temperature, the test data for the FPSC and control module can be found in figure 8 of task 3.2.

Figure 1. FPSC control module



In developing the system monitoring and usage electronics it was first necessary to identify the machine components to be controlled by the microprocessor.

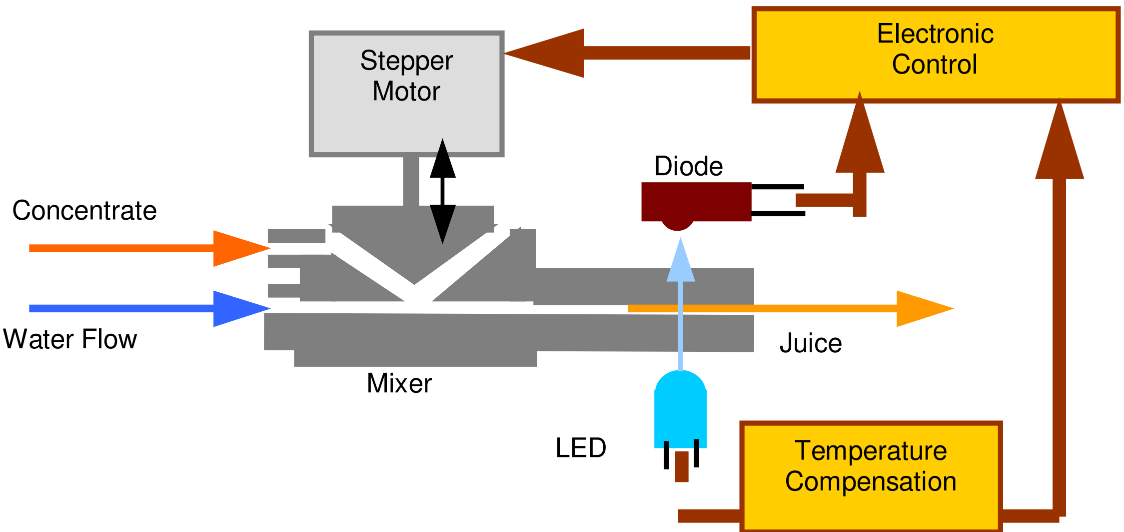
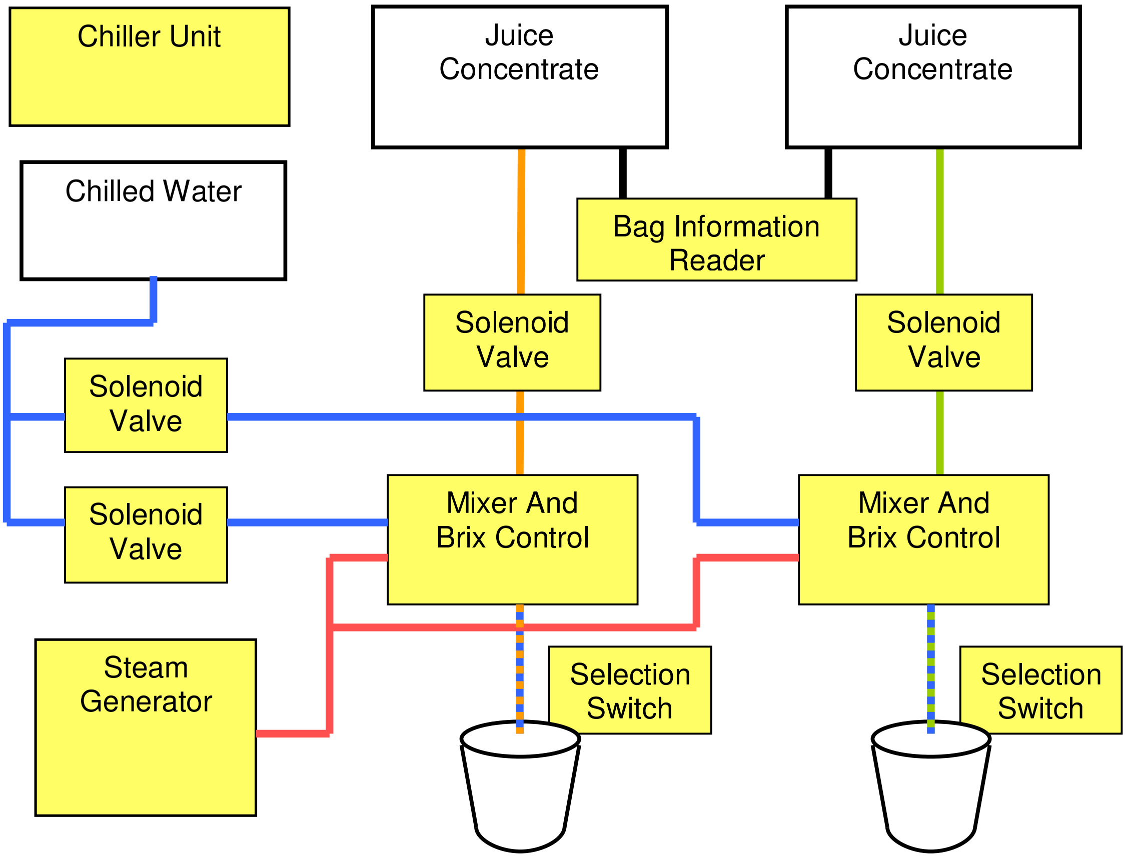


Figure 2. Electronic control of concentration

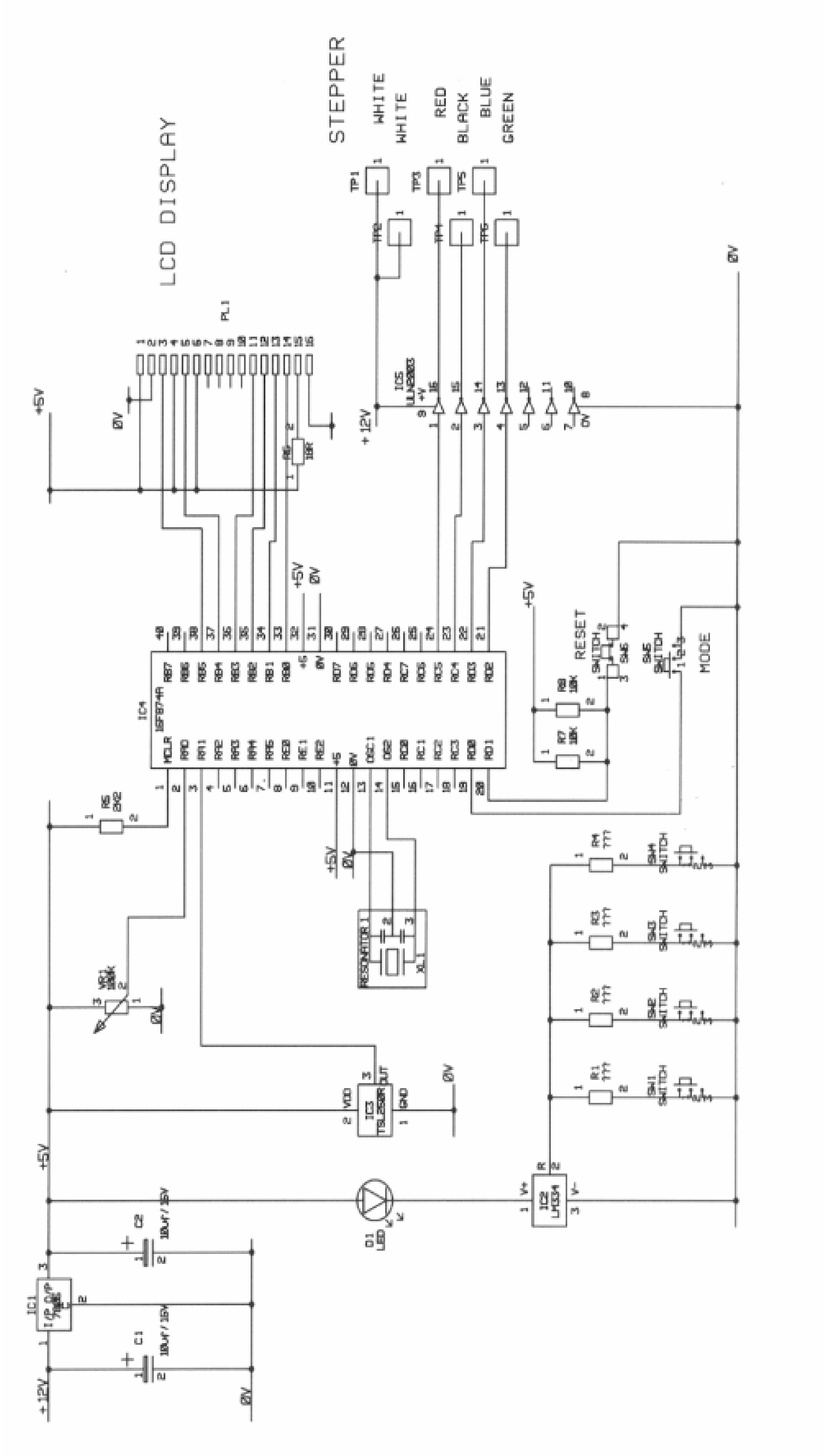
Figure 2 shows the control electronics for the mixing/metering head and the light absorption chamber. This is a sub assembly of the complete control system as shown below in figure 3.

Figure 3. Machine components to be controlled by the microprocessor



This control unit layout is based on a two-flavour machine, but can be easily adapted for several flavours. Figure 4, on the following page, show the circuit layout for the system control.

Figure 4, Circuit layout for control system



Work Package 4 – Hygiene Assurance

Task 4.1 - Steam Sterilisation and Modelling
Task Leader: Partner 3 - SDF

Objectives:

Utilising the system design, a mixing system and refractometer test chamber, from task 2.1. Including the development of a mathematical model for the assessing the interaction between the steam and the internal areas of the mixing, measurement and dispensing system. Tables of predictive results logging steam levels required to effectively reach all areas of the mechanism.

Progress:

Sterilisation and pasteurisation is achieved by a flow of hot water or steam through the mixing chamber. If only pasteurisation is desired, one may flush the mixing chamber using water with a temperature of 90℃. The hot water will heat the wall of the mixing chamber. Once the walls reach a temperature of 70℃, pasteurisation starts.

If sterilisation is required, one may flush the mixing chamber using atmospheric superheated steam with a temperature of 110℃. The steam will heat the walls initially to a temperature close to 100℃. At that temperature the walls start to dry. Once the wall is dry, the temperature will increase further to a maximum close to 110℃. Complete sterility will be achieved once heat intensity comparable to 20 minutes at 120℃ is reached at the coldest spot in the mixing unit where contact with the dispensed product is possible. However in case of dispensing acid products only such a lower heat intensity will be sufficient.

These processes can be described mathematically by mass, momentum and energy balances along with the correct boundary conditions on the walls of the mixing chamber. This section lists the appropriate equations. They will not be derived here. The equations listed here can be found in any standard reference book on fluid dynamics.

Special attention will be paid to the boundary conditions on the walls of the mixing chamber, since they are used to model the complex interaction between steam and these walls. Furthermore, a sterilisation and pasteurisation model will be introduced. The final paragraph in this section will discuss the solution of the equations.

Mass, Momentum and Energy Balances:

The incompressible Navier-Stokes equations were used to model the flow through the mixing chamber. They are:

$$\nabla \cdot v = 0, \tag{1}$$

describing mass conservation and

$$\frac{\partial v}{\partial t} + v \cdot \nabla v = \frac{1}{\rho} \nabla p + \nu \nabla^2 v, \tag{2}$$

describing momentum conservation of the fluid (water or steam).

The conservation of energy can be described by:

$$\frac{\partial T}{\partial t} + v \cdot \nabla T = \alpha \nabla^2 T, \tag{3}$$

when the heat effect of viscous dissipation in the fluid and pressure changes is neglected. Furthermore, it has been assumed that the physical properties of the fluid (e.g. heat capacity and thermal conductivity) are constant.

Thus equations suffice to describe the flow and energy transfer in the mixing chamber. They only need to be supplemented with the appropriate boundary conditions.

Boundary Conditions:

The boundary conditions for the Navier-Stokes equations are straightforward. A velocity is prescribed at the inlet. The pressure is prescribed at the outlet. At the walls, the stick boundary condition is applied. This means that the velocity at all walls must be 0.

The boundary conditions for the energy equation, equation (3), are slightly more complicated. At the wall, the heat flux to the wall is equated to the heat flux through the wall. Since the wall is not part of the model, the latter is modelled using a heat transfer coefficient k. The general boundary condition on the wall is thus given by:

$$\underbrace{-\lambda \nabla T \cdot \mathbf{n}}_{\text{Heat flux to the wall}} + \underbrace{Q}_{\text{Heat source at the wall}} = \underbrace{k(T_w - T_{ambient})}_{\text{Heat flux through the wall}}, \tag{4}$$

where the subscript “w” indicates the temperature at the wall inside the mixing chamber.

The heat source and the heat transfer coefficient remain to be specified. The heat transfer coefficient models the resistance to heat transfer of the wall.

When the heat capacity of the wall may be ignored, the heat flux through a wall with thickness d and thermal conductivity λ_w is given exactly by: $\lambda_w/d\,(T_w - T_{ambient})$.

One may ignore the thermal capacity of the mixing chamber wall provided that the heat loss through the wall is much larger than the heat capacity of the mixing chamber. This seems to be justified, especially in the final design where the mixing chamber will be as light as possible.

At the same time, the insulation of the mixing chamber will then be relatively poor. Making the assumption that the heat capacity of the mixing chamber is negligible, one may easily see that:

$$k = \frac{\lambda_w}{d}. \tag{5}$$

This equation for the heat transfer coefficient has been used throughout the model. Note that the wall thickness is not a constant. It has been specified as a function of the position on the wall.

The heat source, Q, is the result of evaporation and condensation of steam on the wall. The condensation is not calculated directly in the model. Therefore, it must be estimated using a boundary layer model. The source term is then described as:

$$Q = h\left(p_s\left(T_{center}\right) - p_s\left(T_w\right)\right)\Delta h_{evap}, \tag{6}$$

where the mass transfer coefficient h is derived from standard Nusselt number correlations.

The saturation pressure of water vapour as a function of temperature can be taken from the relations provided by the IAPWS [1]. This completes the description of the boundary conditions.

Sterilisation and Pasteurisation Model:

The difference between sterilisation and pasteurisation is the kind of organisms that are killed. The aim of pasteurisation is to kill vegetative microorganism. Bacterial spores that can become active and produce new organisms are not affected. During complete sterilisation, the spores are killed as well. However because bacterial spores cannot germinate easily at pH below 4 a complete sterility will not be necessary in case of dispensing only acid products.

Both processes can be described by keeping track of an effective pasteurisation or sterilisation time. This effective time is usually referred to as F-value. The equation for this value is:

$$\frac{\partial F}{\partial t} = 10^{\frac{T - T_{ref}}{z}}. \tag{7}$$

F has units of time (usually minutes). The physical interpretation of F is that the heat treatment given to that location is equivalent (in terms of killed micro-organisms) to a heat treatment with duration F at a temperature T_{ref}. For sterilisation, the reference temperature is 121.1°C and z is 10°C. Thus if F for sterilisation is 5 minutes at a certain location, then that location is as sterile as it would have been if it were sterilised at 121.1°C during 5 minutes.

For pasteurisation, the reference temperature is 72°C and z is 8.2°C. The boundary conditions for Equation (7) are that there is no flux of F through any boundary.

Summary:

- Standard equations of fluid dynamics are solved
- The wall heating is simulated
- Wall heating occurs through direct heat exchange and condensation / evaporation
- The wall thickness is taken into account
- Solution method: equations are solved using FEMLAB, a finite element program
- Development of mathematical model complete, calculation currently being performed, results to follow

Task 4.2: - Hardware Implementation and Tests (D13)
Task Leader: Partner 3 - SDF

Objectives:

To design and build a sterilisation test rig through the integration of the steam generation system from task 3.3 and the mixing and test chamber development from task 2.1.

Steam cleansing test trials, using microbial growth data form task 1.4 the system will be tested through an ambient temp range of 30 - 40ºC and under simulated vending use pattern. Using the recommended frequencies for cleaning from task 1.4, and required steam levels from task 4.1. The system will be tested for microbial growth before and after steam cleaning using dip and contact slides. Tables quantifying cleaning effectiveness, starting with a microbe free system, showing recommended cleaning frequencies, showing juice dispensed, recommended time intervals between cleaning, microbial growth before cleaning and microbial growth after cleaning.

Progress:

Materials pre-selection:

Before and partly parallel to the cleaning trials, research was performed in order to make a first selection of (engineering plastic) materials for both the mixing chamber and the light absorption chamber taken into account the different cleaning methods that are optional for the future vending machine.

Besides in-line cleaning with cold, hot water and steam, off-line cleaning of the components in a dishwasher was taken into consideration. During the project Autonumis asked for more insight in other sterilisation/disinfection technologies besides using overheated steam, more precisely using ozone in gaseous form or dissolved in water. For that reason the resistance of the materials against ozone was taking into consideration as well.

Durability tests:

For a reliable measurement of the Brix value it is essential that the material of the light absorption chamber will not be affected by the products dispensed or by mechanically influences. The durability of the intended material for the light absorption chamber being acrylic (PMMA) or polystyrene (PS) has been tested against the durability of optical glass (OG) as a reference material.

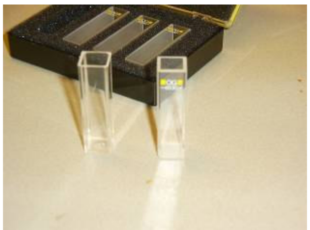
Not all of the plastic materials are an option for each cleaning method: in case of pasteurisation the use of PS is doubtful, in case of sterilisation the use of PMMA is doubtful.

Material	Maximum Temperature	Processes Accepted	Not Accepted / Doubtful
Polystyrene (PS)	60 °C - 80 °C	Rinsing cold / warm water	Pasteurization > 70 °C
Acrylic (PMMA)	80 °C - 105 °C	Pasteurization > 70 °C	Sterilization > 110 °C
Optical Glass (OG)	>> 200 °C	All	-

In this preliminary test the three materials (standard macro cells, size 12.5 x 12.5 x 45 mm) have been exposed to four liquids for a longer period of time, being approximately 3 months:

- Concentrated fruit juice (Celcon, Brix 55)
- Concentrated iced lemon tea
- 60% lactic acid
- 1N HCl

During the exposure time the materials have been judged daily in the beginning and later on weekly or monthly with water. On each occasion the materials have been rinsed and judged visually for adverse effects. In the end the light transmission is measured in comparison with a non-abused material (spectrophotometer).



Exposure tests of different cells

Results of the exposure tests:

- Except for the deterioration of the PMMA material when exposed to 60% lactic acid, no visible changes of the materials were noticed after exposure for a period of approximately 3 months,
- Spectrophotometric measurements at the end of the exposure time also did not show significant changes compared to unabused cells.

Dishwasher safety:

For a number of transparent plastics there is a guideline for the dishwasher safety of those engineering materials. These general guidelines come from material suppliers as well as industrial producers of, for instance, plastic tableware and dinnerware where crazing and clouding of the products must be avoided or postponed for a longer period. However, the final material grade has to be defined in cooperation with a material supplier. In the material table a number of transparent engineering plastics and the dishwasher safety are given.

Ozone resistance:

During the project Autonumis asked for more insight in other sterilisation and disinfecting technologies besides using overheated steam, more precisely using ozone in gaseous form or dissolved in water. Within TNO the microbiologists had experience with ozone treatment as well. Efficacy tests with the supplied ozone generator were carried out in the project to establish the disinfection effect of ozone.
An important design aspect is that ozone might cause severe corrosion of metals and also has an effect on polymer materials, e.g. plastics and rubbers.

Known ozone resistant materials are (source Lenntech):

- Stainless steel (300 series)
- Polyvinylchloride (PVC)
- Acrylic (PMMA)
- Teflon (PTFE)
- Kynar (PVDF)
- Glass

In the material table the ozone resistance of the acrylic engineering plastics is given.

Materials conclusion:

In the next table the various material aspects are combined. Besides the required transparency for the light measurement chamber and the resistance against temperature use, dishwasher conditions and ozone effects, the costs of the materials are given relatively.

Material	Max Temp short time use	Max Temp continuous use	Dish-washer safety	Ozone resistance	Costs	Transparency
Polystyrene (PS)	80 °C	60 °C	Good	-	€	Clear
Acrylic (PMMA)	105 °C	80 °C	Bad	+	€	Clear
Acrylic blends (SAN)	95 °C	85 °C	Best	0/+	€€	Clear
Polypropylene (PP)	140 °C	105 °C	Best	-	€	Translucent
Polycarbonate (PC)	140 °C	125 °C	Best	-	€€€	Clear
Acetal (POM)	140 °C	90 °C	Best	-	€€	Opaque

At lower temperatures, relatively low cost plastics PS and PMMA are a first option. At higher operating temperatures PC has the best performance, but is the most expensive. However, in order to make a final selection, the total application scenario has to be taken into consideration.

Some relevant scenarios for plastic application:

Injection moulding of a mixing and measurement chamber of the same material, possibly designed as an integrated product, in the future vending machine are:

1. Permanent use, long periods, in-line cleanable
   - PMMA (short time use steam, ozone)
   - PC (continuous use steam)
2. Semi-permanent use, shorter periods, dish washable
   - PS
   - PC
3. Disposable use, short periods
   - PS
   - PMMA

In the research phase of the project so far there is not an integrated product design in which the transparent light measurement chamber is combined with the mixing unit in one producible part or assembly. When two separate products are to be produced and installed in the vending machine, different materials can be applied: a transparent light measurement chamber with an non transparent mixing unit. The aspect of transparency of the material then is no longer decisive as far as the mixing unit is concerned. The mixing unit can be made of opaque or full coloured POM for instance. However for hygienic reasons (visual inspection) a transparent mixing unit is preferred.

When a cleaning scenario eventually is chosen and the process specifications are known, the material specifications have to be checked and discussed with the preferred supplier. Aspects like for instance the so called hydrolysis effect, deterioration caused by the absorption of water, in case of an in-line cleaning process or the effects of chemical detergents in case of a dishwasher scenario have to be taken in consideration.

Construction of the test rig:

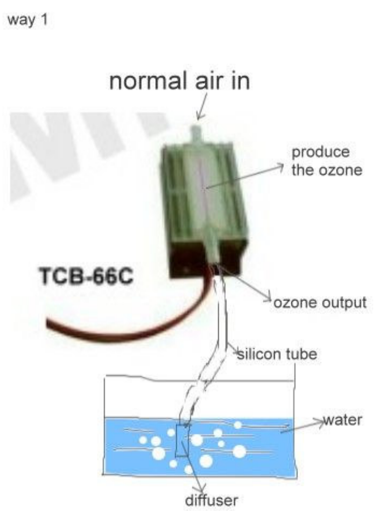
Because of the small scale of the equipment, the limited amount of water that can be used as well as the specific demands for cleaning of the dispensing unit without detergent, the standard test circuits at TNO used for testing of equipment according to EHEDG protocols proved to be not suitable.

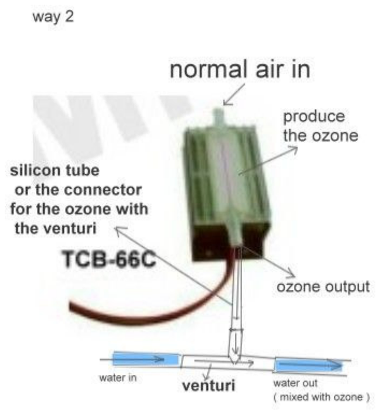
The circuits are oversized, have a large water flow and operate at higher pressures than vending machine conditions (1,5 bar). The circuits do no match with the relatively small scale and limited amounts of water flow in a vending machine.

Therefore, a more customized integrated test rig has been developed in which the steam generator, mixing unit and light absorption chamber are combined. This test rig is on a vending machine scale and with vending machine conditions in relation to water flow and pressure. By means of the steam generator several cleaning procedures with water and steam have been evaluated as intended.

Basically variations have been made in pre-rinsing methods with cold and/or warm water and final rinsing methods with warm and/or hot water combined with the time and amount of water needed to obtain optimal results. After that, pasteurisability with hot water and steam was investigated in a similar setup.

In an intermediate research step, the disinfecting effect of ozone was investigated. For that purpose an ozone generator was integrated being the Trump TCB-66C.
The ozone was dissolved in the water via the venturi principle. The given capacity of the generator is 500 mg Ozone/h.





Ozone generator TBC-66C

Venturi effect

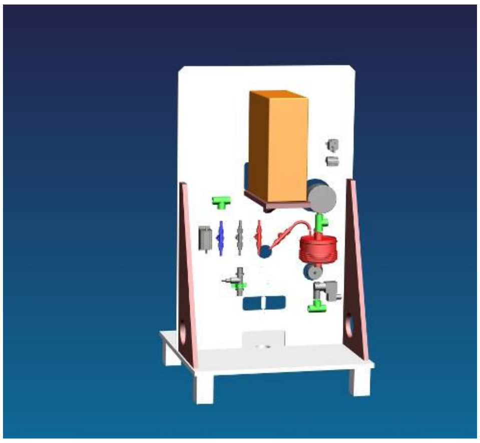
What has to be taken into account are the safety (and psychological) aspects, in this case the Maximum Acceptable Concentration (MAC) of ozone that may occur in or around the vending machine. For a period of 15 minutes a maximum MAC-value of 0,3 ppm in the air is allowed (to compare: during a working day of 8 hours the MAC-value is 0,06 ppm). From experiments we know that the ozone smell can be very noticeable and penetrating.

Cleaning procedures in the vending machine might have to be performed during the night or the early hours of the morning when no one is present, or with lower ozone concentrations during a longer period of (rinsing) time.

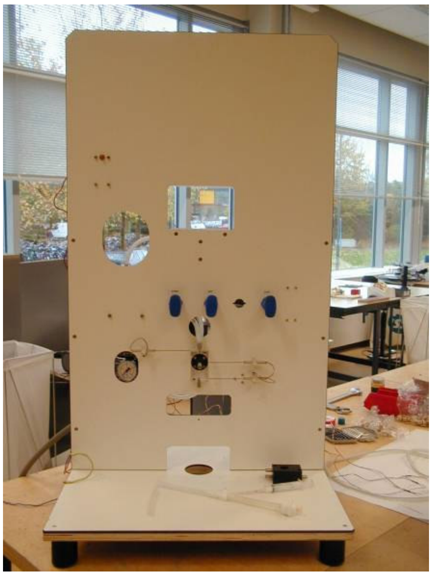
The commercial available ozone generator has been applied in order to be able to get a first impression of the efficacy and effects compared with hot water and steam cleaning of the system.

Integrated in the rig are the modified steam generator (with hot water outlet), the ozone generator, the mixing unit and the light measurement chamber (an open cell).
The configuration of mixing unit and the light measurement chamber is like in a vending machine. With a bag in box system concentrated juice can be supplied to the mixing unit.
The customized test rig was designed in 3D CAD (Unigraphics), constructive elements (frame, brackets) were produced, components (valves, fittings, pipes) were purchased and the rig was assembled. The test rig was constructed for manual operation.

The test rig was transported to the TNO premises in Zeist for the actual testing.



3D CAD design of the test rig

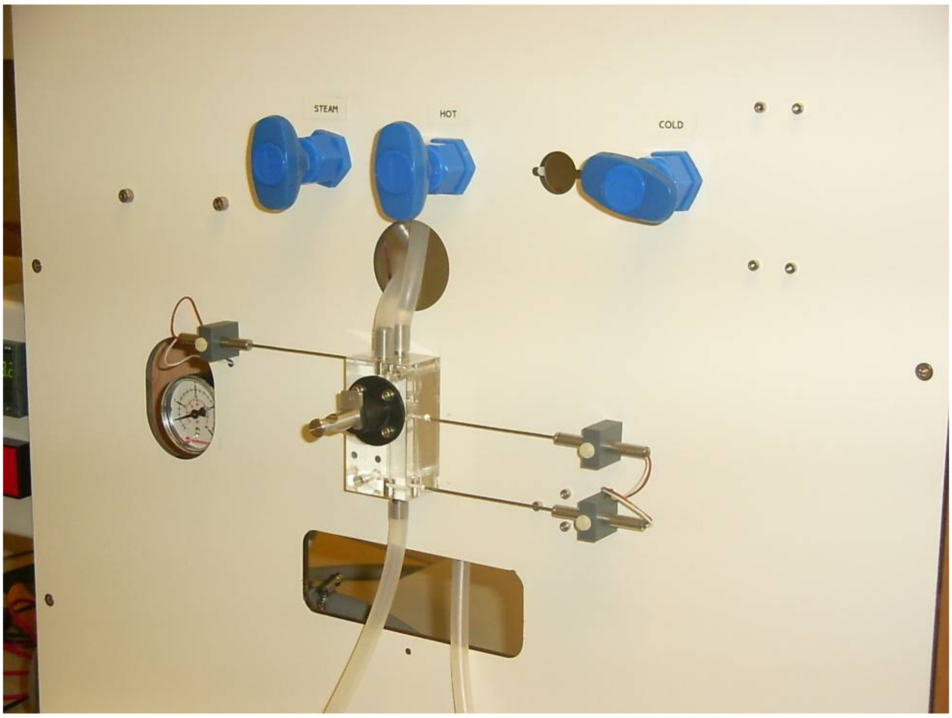



Test rig under construction in Eindhoven

Steam generator

Ozone generator


Test rig ready for operation in Zeist

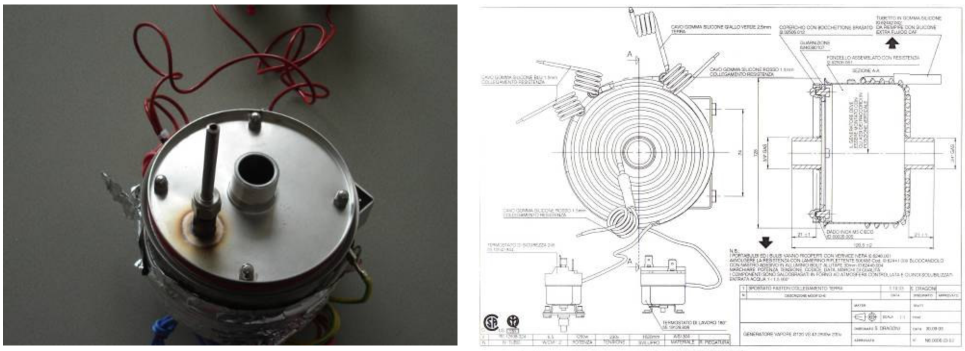


Test rig front panel with mixing unit, thermo couples, pressure meter and control valves

As specified the steam generator should produce:
A flow of hot (> 90°C) water: 200 ml within 30 s
A flow of superheated (~110°C) atmospheric steam: 30 ml/s

Required calculated power:
Steam generation: 100 W
Water heating: 1.5 kW for heating in 1 minute
Superheating: 20 W or less

The selected steam generator, model N6.006.03.02-2500W from Thermal Elements, was modified in order to be able supply hot water additional to the steam production.


The modified steam generator with hot water outlet

Experiments with the test rig:

The cleaning priorities/sequence of the experiments was based on the following cleanability and pasteurisability steps:

- If cleaning with cold water proves to be a promising option, ozonisation will be (preliminary) examined.
- If cleaning with cold water proves to be insufficient, pasteurisation will be further examined.
- If pasteurisation with hot water proves to be insufficient, steam rinsing will be further examined to reach the required heat intensity (at least 2 minutes 70°C at the coldest spot).

Inoculation experiments with juice dispenser:

To test chemically on remaining spores or test fluid present seems to be a difficult and uncertain path: in this case it is very hard to determine which markers / materials have the proper reaction with elements in the juice concentrate. To find the right markers/materials would be very time consuming.

An easier way is to detect remaining soil by visual inspection. Therefore a second, transparent, acrylic (PMMA) mixing unit was produced by TNO, based on the existing CAD model of Pera.

The experiment set up was the following:

- Juice inoculated with a mixture of lactic acid bacteria and yeast was brought into the juice dispenser en left there for one hour;
- Than the dispenser was rinsed with cold water (12-14°C) at 1 bar (3 seconds through juice inlet, 3 seconds through venturi inlet);
- After this standard cleaning 10 taps of 200 ml water (circa 1juice inlet : 5 venturi inlet) were gathered and analyzed for remaining lactic acid bacteria and yeast;
- Subsequently the dispenser was filled with inoculated juice and left there for 3 days;
- Than a similar standard cleaning followed by 10 taps of 200 ml was performed
- The same procedure was repeated with juice left in the dispenser for 1 week.

Results inoculation experiments

Lactic acid bacteria cultures used				
L. plantarum	1.21E+08	per ml		
L. sake	3.10E+07	per ml		
Yeast cultures used				
S. cerevisiae	7.70E+06	per ml		
Z. bailli	1.65E+07	per ml		
Yeast from pinapple	1.77E+07	per ml		
	Lactic acid bacteria		Yeast	
Juice	< 1	per ml	< 1	per ml
Juice inoculated	2.24E+06	per ml	5.90E+05	per ml

Results cleaning after 1 hour					
		Lactic acid bacteria		Yeast	
Rinse water		26000	per ml	6500	per ml
Tap 1		102	per 100 ml	17	per ml
Tap 2		12	per 100 ml	11	per ml
Tap 3		14	per 100 ml	27	per ml
Tap 4		6	per 100 ml	36	per ml
Tap 5		2	per 100 ml	12	per ml
Tap 6		< 1	per 100 ml	14	per ml
Tap 7		70	per 100 ml	19	per ml
Tap 8		2	per 100 ml	13	per ml
Tap 9		2	per 100 ml	9	per ml
Tap 10		8	per 100 ml	9	per ml

Results cleaning after 3 days					
		Lactic acid bacteria		Yeast	
Rinse water		3130	per ml	11400	per ml
Tap 1		222	per 100 ml	1610	per ml
Tap 2		300	per 100 ml	229	per ml
Tap 3		240	per 100 ml	65	per ml
Tap 4		130	per 100 ml	36	per ml
Tap 5		86	per 100 ml	12	per ml
Tap 6		68	per 100 ml	180	per ml
Tap 7		4	per 100 ml	2	per ml
Tap 8		6	per 100 ml	3	per ml
Tap 9		18	per 100 ml	6	per ml
Tap 10		22	per 100 ml	3	per ml

Results cleaning after 6 days					
		Lactic acid bacteria		Yeast	
Rinse water		410000	per ml	4300000	per ml
Tap 1		1090	per ml	> 3000	per ml
Tap 2		127	per ml	3290	per ml
Tap 3		57	per ml	970	per ml
Tap 4		44	per ml	960	per ml
Tap 5		57	per ml	1140	per ml
Tap 6		71	per ml	950	per ml
Tap 7		34	per ml	560	per ml
Tap 8		31	per ml	620	per ml
Tap 9		44	per ml	360	per ml
Tap 10		75	per ml	820	per ml

Preliminary conclusions inoculation experiments:

Cleaning after 1 hour

- After cleaning the dispenser is visually clean;
- Most of the lactic acid bacteria and yeast are removed by the rinsing procedure;
- In the first 10 taps a low declining number of micro-organisms is found;
- Although initial numbers of yeast are lower than initial numbers of lactic acid bacteria, higher numbers of yeast are found in the tap.

Cleaning after 3 days

- After cleaning the dispenser is visually clean;
- Compared to the results of the rinse water after 1 hour the lactic acid bacteria declined and the yeast increased marginally in number;
- The numbers of lactic acid bacteria and yeast in the taps were somewhat higher than after 1 hour but still rather low and declining.

Cleaning after 6 days

- After cleaning the dispenser is visually clean;
- Compared to the results of the rinse water after 3 days a substantial increase in numbers of lactic acid bacteria and yeast has occurred;
- This relative high level of contamination resulted in higher counts in the first 10 taps.

General conclusion inoculation experiments

- Cleaning the dispenser unit with cold water results in a visually clean dispenser and low declining microbial numbers in the first taps;
- Complete removal is not reached as can be expected when only a cleaning step is applied;
- A prolonged stand still time of the vending machine might result in an undesired increase of microorganisms in the dispenser or the tubes;
- Even in this worst case situation the remaining numbers of micro-organisms in the first taps are low and not relevant concerning the quality and food safety of dispensed low pH products;
- In EG guideline 98/83/EG for the quality of tap water a limit of 100 microorganisms per ml is mentioned.

Rinsing experiments with concentrates containing cells:

Additional to former rinsing tests a final test was performed with juice concentrate containing cells because this might be more difficult to clean. The general cleaning procedure as used before was performed. Juice concentrate with cells was brought into the juice dispenser and then left for one hour.

The dispenser was rinsed with cold water (12-14℃) at 1 bar (3 seconds through juice inlet, 3 seconds through venturi inlet). Subsequently the dispenser was filled with juice concentrate with cells and left there for 3 days.

A similar standard cleaning procedure was performed, which procedure was repeated with juice left in the dispenser for 1 week.

On all occasions the juice dispenser was visibly clean after the rinsing process. However after 3 and 7 days holding time some remaining juice concentrate with cells was not removed from the tubing below the dispenser as a result of dry out.

Cleaning the dispenser unit with cold-water results in a visually clean dispenser even in case of juice concentrates with cells. Insufficient cleaning can be expected at spots where remaining juice concentrate especially with cells is able to dry out for instance at the end of the tubing.

Efficacy test with ozone generator:

The experiment set up:

- Sterile tap (3 litre) water inoculated with a mixture of yeasts and lactic acid bacteria was lead through the venturi connected with the ozone generator;
- The water was lead through with a flow of 1.5 l/minute by means of a tube pump;
- The ozone treated inoculated water was collected in a sterile vessel after disposing the first 250 ml;
- In between the tubing was rinsed with sterile water for 10 sec;
- The collected ozone treated inoculated water was lead again through the venturi and collected in a new sterile vessel after disposing 250 ml;

- This procedure was repeated for a total of 10 times;
- After each run a sample was taken and diluted 1 : 10 in peptone physiological saline to inactivate the ozone;
- All samples were microbiologically analyzed on remaining yeasts and lactic acid bacteria.

Results efficacy test

			Lactic acid		Yeast
			bacteria		
			per ml		per ml
Vessel 1	control		1,70E+05		7,70E+04
Vessel 2	ozone treatment 1x		1,80E+05		8,20E+04
Vessel 3	ozone treatment 2x		1,10E+05		8,40E+04
Vessel 4	ozone treatment 3x		6,40E+04		7,50E+04
Vessel 5	ozone treatment 4x		1,50E+04		8,10E+04
Vessel 6	ozone treatment 5x		1,60E+03		6,40E+04
Vessel 7	ozone treatment 6x		2,50E+02		6,40E+04
Vessel 8	ozone treatment 7x		1,20E+02		4,40E+04
Vessel 9	ozone treatment 8x		3,00E+01		3,40E+04
Vessel 10	ozone treatment 9x		< 10		3,10E+04
Vessel 11	ozone treatment 10x		< 10		1,20E+04

Preliminary conclusions efficacy test:

- The amount of ozone produced with the available ozone generator showed some antimicrobial effect;
- The effect on lactic acid bacteria was clearly better than on yeast;
- Because yeast cells are a factor 100 larger than bacterial cells they are probably less affected by small amounts of ozone;

- The decontaminating effect of ozone as produced by the available ozone generator will probably not be sufficient for decontamination of all surfaces of the juice dispenser and tubing system, taking into account that sessile cells are more difficult to inactivate than planktonic cells.

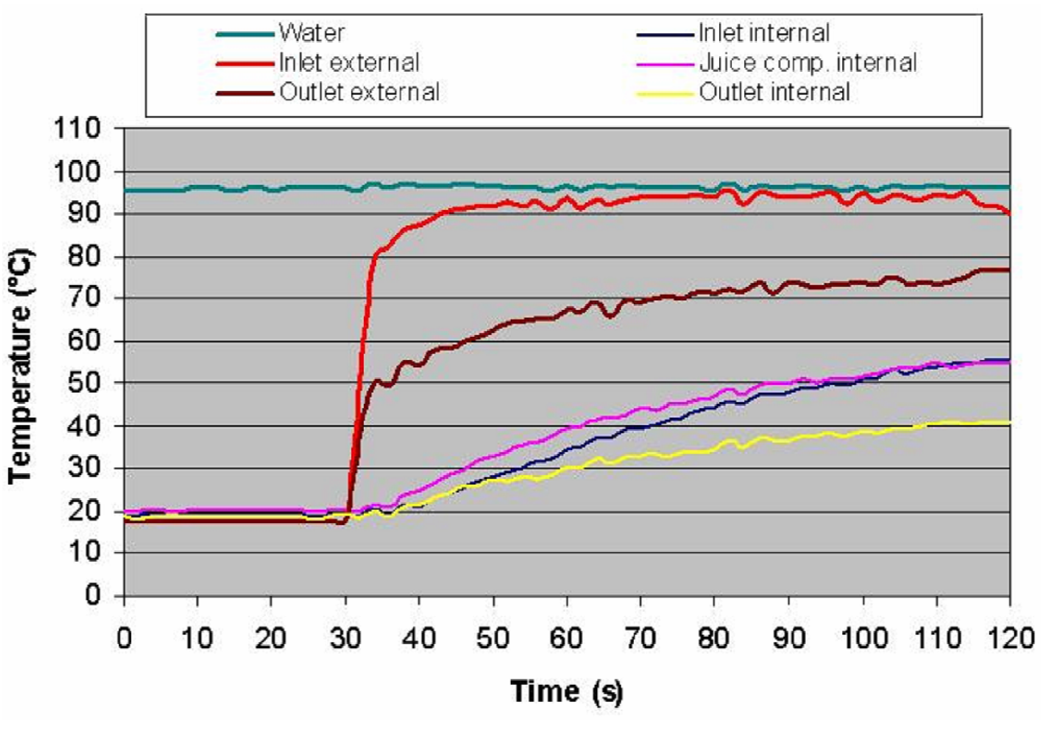
Follow up efficacy test:

- The ozone generator used (according to the label 500 mg/hr) is not powerful enough to produce sufficient ozone to inactivate bacteria and yeast in a short enough time;
- An option is to evaluate, test and compare the efficacy of an ozone generator with higher capacity (1000 mg/hr).

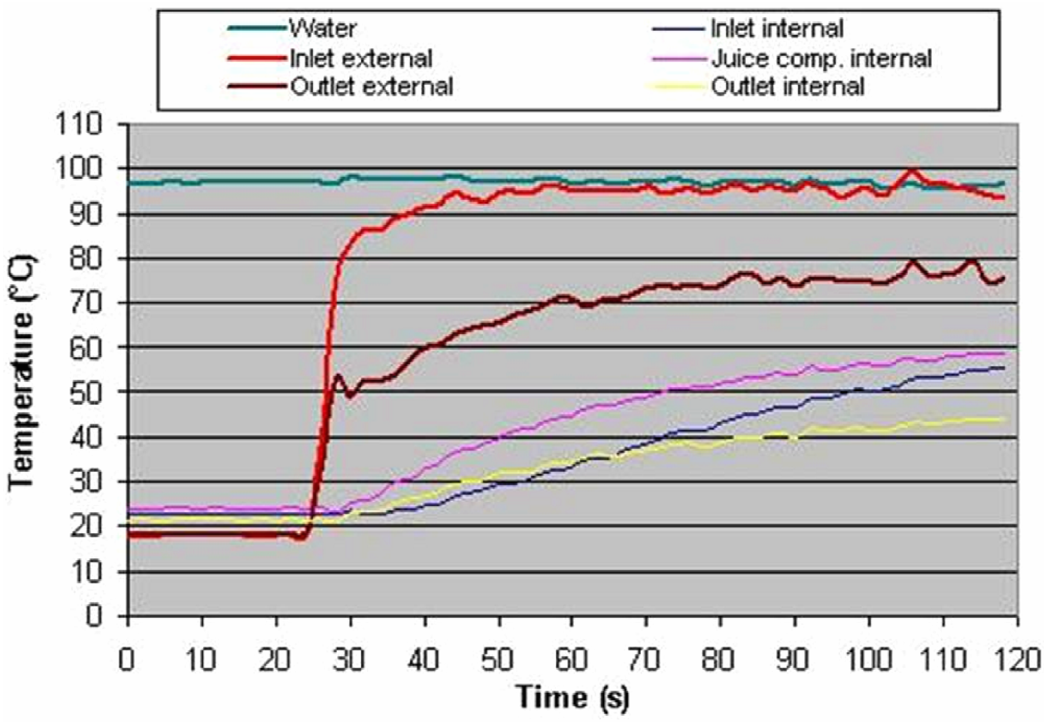
Pasteurisation:

Pasteurisation was further evaluated by heating the mixing chamber with hot water and steam. Temperature measurements showed that steam pasteurisation is most effective in a short time reaching higher temperatures and using smaller amounts of water than with the hot water treatment: 200 ml for steam compared with 3 – 4 liter hot water! The efficiency of the steam process is much higher due to direct heat exchange in the mixing unit as a result of the relatively large condensation effect.

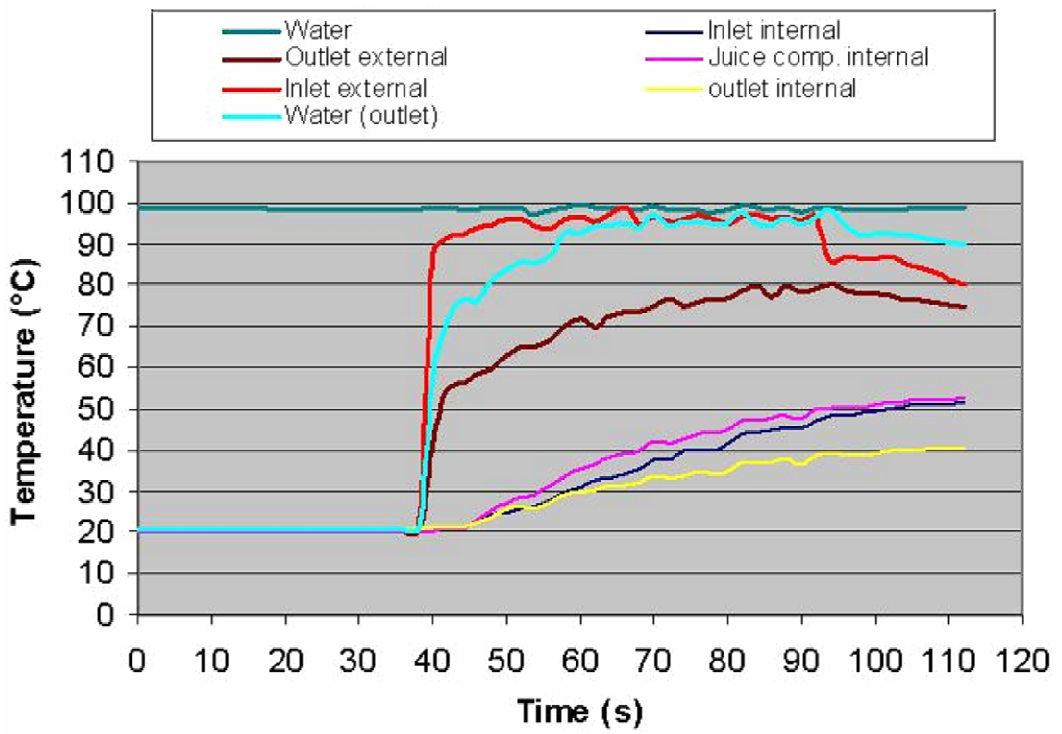
Pasteurisation with hot water ~ 95 °C



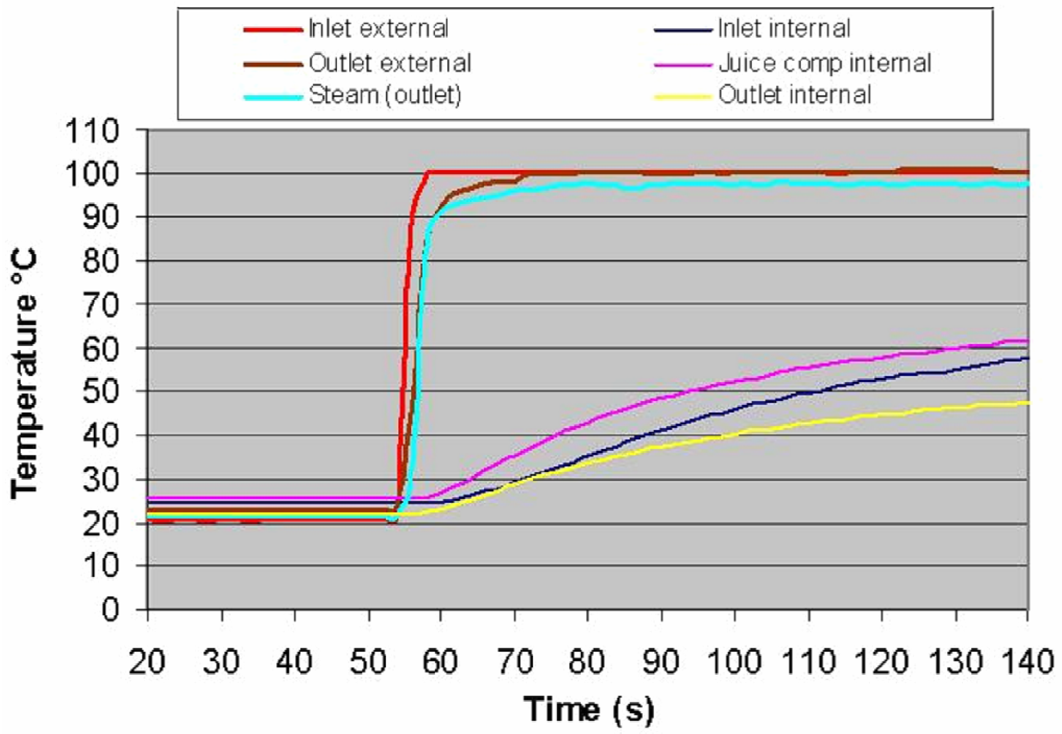
Pasteurisation with hot water ~ 97 °C



Pasteurisation with hot water ~ 99 °C



Pasteurisation with steam ~ 105 °C



Conclusions experiments:

- The mathematical models are in compliance with the results of the performed experiments;
- Cleaning the dispenser unit with cold water results in a visually clean dispenser and low declining microbial numbers in the first taps;
- Even in this worst case situation the remaining numbers of micro-organisms in the first taps are low and not relevant concerning the quality and food safety of dispensed low pH products;
- Cleaning the dispenser unit with cold water results in a visually clean dispenser even in case of juice concentrates with cells;
- Insufficient cleaning might be expected at spots where remaining juice concentrate, especially with cells, is able to dry out (e.g. the end of the tubing);
- The decontaminating effect of ozone as produced by the available ozone generator is limited and will probably not be sufficient for decontamination of all surfaces of the juice dispenser and tubing system, taking into account that sessile cells are more difficult to inactivate than planktonic cells;
- Pasteurisation with hot water (~ 90 °C) requires a water flow during 2 – 3 minutes in order to reach a temperature of ~ 70 °C in every spot in the system; the used water volume is 3 – 4 litres;
- Pasteurisation with steam (~ 105 °C) requires a steam flow during 10 – 15 sec in order to reach a temperature of ~ 70 °C in every spot in the system; the used water volume is ~ 200 ml.

A theoretical bottleneck being the hygienic aspects of a three-way valve or manifold in the system has been discussed with the experts. Mix proof valves in general are designed for sanitary and aseptic applications in the dairy, food, brewing, beverage, and pharmaceutical and biochemical industries. The conclusion was to focus on the cleanability of the mixing unit and light absorption chamber first. A hygienic review of the complete prototype to be developed in due time, should provide feedback on this hygienic risks and provide insight in design steps to be taken in order to reduce or eliminate this risk.

Recommendations engineering phase (Q4-2006):

- Validation of the results (the mathematical models and experiments) with a final prototype of the juice dispenser with interfaces (tubing, connections, valves etc.);
- Hygienic review of the prototype of the juice dispenser against the design criteria of the National Sanitation Foundation (NSF) and the European Hygienic Engineering & Design Group (EHEDG);
- Monitoring of the cleanability of the prototype of the juice dispenser during an actual use situation for (TNO) certification purposes;
- Formulation of a final cleaning procedure for the juice machine based on the monitoring of the cleanability of the prototype of the juice dispenser;
- Based on the results of these review and tests TNO can issue a TNO statement about Hygienic performance of the Autonumis juice dispenser.

Task 4.3: - Electronic Hardware & Software (D14)
Task Leader: Partner 3 – SDF

Objectives:

Electronics, sensors and control algorithms, using the cleaning frequency data from task 1.4, the required steam levels from task 4.1 and test data from task 4.2, to implement the steam-cleaning regime. Tests using parameters from task 4.2 to ensure cleaning regime is to specifications, tables logging cleaning frequency and steam levels for comparison with recommendations from previous tasks..

Progress:

Cleaning method and frequency:

The research activities undertaken focused on the formulation of the cleaning method and procedure for the juice vending machine.

In order to overcome the set back in the development of a test rig, extra capacity (man-hours) was brought into the project. An additional mid period review, of the test rig, was organized to evaluate the test rig and review preliminary results. Following the mid period review the research focus for the next half period was established.

The preliminary concept for in-place cleaning procedures aimed at visible clean conditions is given in the next table. The concept is based on existing knowledge and the results of the test experiments.

	Rinsing with cold water	**Rinsing with cold water followed by hot water or steam pasteurization (to reach at least 2 minutes ~70 °C at all spots)**
Fruit juice pH < 4	Every day	Every week or in case of shutting down or starting up the machine
Other Drinks Neutral pH	Not recommended	Every day

For ozone disinfection there was no in-place cleaning procedure described so far. Since ozone disinfection is not considered an alternative given the test results obtained, a preliminary ozone procedure has not been determined any further. The project focuses on the juice vending, but for future developments drinks with other pH levels were taken into account as well.

Test rig and control electronics:
The specifications and development of the test rig focused on the application and integration of the steam generator. The ozone generator was originally not included in the project but added in a later stage as an alternative disinfection technology. Ozonisation is (both technically and commercially) an interesting option since the available generator is compact, very low cost and operates with cold water at low pressure, no heating is required. The hygienic tests however proved the necessity of the use of steam for cleaning.

Specifications of the steam generator were formulated in task 4.2:

Power

- Approximately 1.5 kW for heating water
- Approximately 100 W for steam generation
- The apparatus should be able to switch easily between the two power levels.

Volume

- The unit should be able to store between 0.3 and 0.7 l water.
- It should be possible to measure the water level in order to control the inlet valve.
- The apparatus should fit in a cube with sides of 20 cm.

Inlet

- The unit should accept water at a mains pressure of 1.5 bar. The pressure inside the apparatus should be 1 bar.

Flow

- The unit should provide 200ml water in 30 seconds.
- Preferably, it should be possible to allow a pulsed flow of water.
- It should provide 30 ml/s of steam during at least 5 minutes.

Measurement and control

- Manual control of the temperature by means of a temperature controller
- Optional control of the unit using LabVIEW. In order to make this possible, the heaters and valves should accept volt-signals (preferably 0-5 V) to switch them on and off.
- Level sensing or thermostatic control of the water volume in the generator
- Pressure sensing in the steam compartment or steam outlet.

Frame

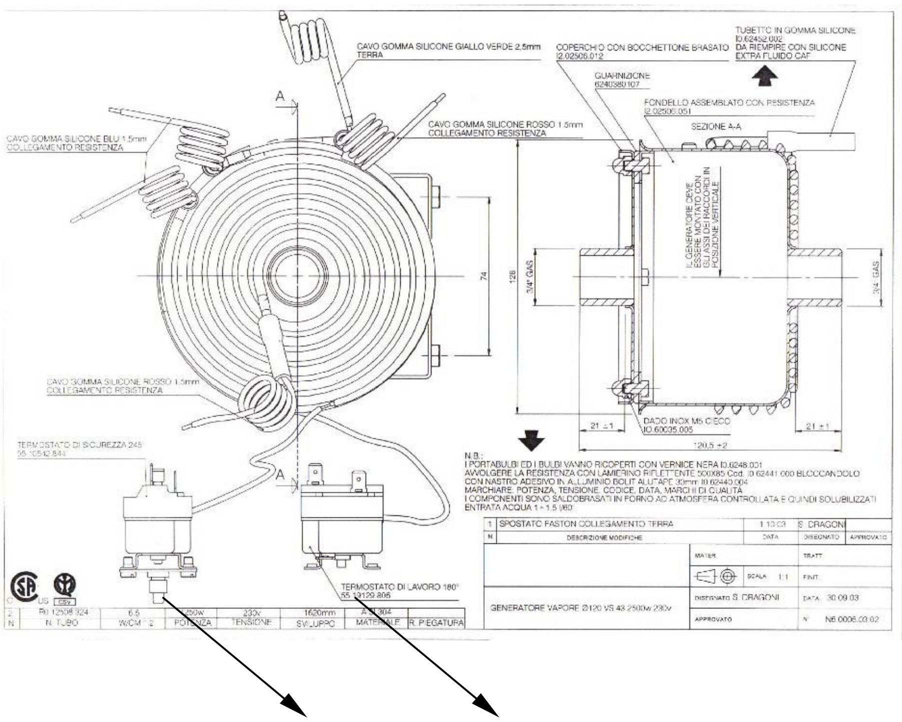
- The generator should be built in a frame so that it can stand on its own.
- Cables for power, measurement and control should be easily accessible.

Connections

- The connection to the mains and to equipment downstream will be made using Swagelock® components. The inlet and outlet pipes should be standard size pipe material.

The selected steam generator, model N6.006.03.02-2500W from Thermal Elements is applied in professional coffee machines (type espresso / cappuccino).
The volume ~ 125 x 125 mm, excluded two safety thermostats. The cost price of the steam generator is approximately 45 Euro at larger quantities.

The cleaning sequence in the test rig proceeds as follows. The generator is filled with water that is heated to 90°C. With a thermo couple (T0) the temperature of the water / steam vessel is monitored during the tests. The generator itself has an integrated safety thermostat (245°C) in order to avoid dry cooking of the generator. The water level in the vessel is monitored by means of a safety thermostat (150°C) and regulated with a solenoid inlet valve. The water inlet can also be manually operated through a push button.

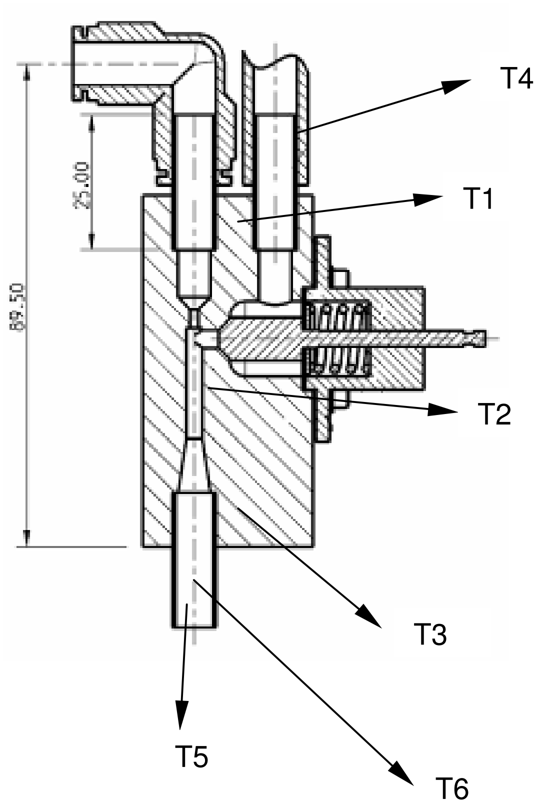


Safety thermostats 245°C 150°C

The control circuit for regulating and maintaining the water level in the vessel is part of the test rig. Once the water reaches the desired temperature, a valve is manually opened to rinse the unit. After a fixed period, the valve is manually closed and the steam outlet is manually opened.

Steam is produced at a constant rate by controlling the heating power. The steam flow is maintained until the surface of the unit reaches a temperature of 105°C.

The temperature inside the mixing unit is monitored at 3 points (through thermo couples) in order to log both the outer and inner temperatures during the cleaning tests (T1, T2 and T3)



During the tests with hot water and steam 3 additional thermo couples were mounted (T4, T5 and T6), measuring the temperature on the surface of the in- and outlet pipe of the mixing unit as well as the temperature of the out coming water / steam inside the outlet of the unit, measured via a hole in the tube.

The temperature controller used in the test rig is a standard commercial available 2116 from Eurotherm Controls.

This is a miniature PID temperature controller with heating, cooling and alarm outputs. Self-tuning is included to optimise control performance without the need for specialist knowledge or training. A universal input is configurable for nine thermocouple types, the PT100 resistance thermometer and linear 4-20mA. Two outputs are provided, a logic output to operate a solid-state relay and a relay output to operate contactors or solenoids. Either output can be configured for heating, cooling or alarms. A timer function is provided which can start or stop a process at the end of a set period.

In the design and construction of the test rig no customized hardware or software is developed in the project. Standard parts and components have been used and the test rig was operated manually.

The necessary electronics, sensors and control algorithms to establish a steam cleaning regime in the actual vending machine can be adapted to and integrate with the control electronics as it is being developed in the consortium. The activities of the research performed by TNO focused on the hygienic and microbiological aspects of the cleaning process with extra work effort to investigate the possibility of ozone disinfection as an alternative or additional technology for steam cleaning.

Work Package 5 – Prototype Integration

Task 5.1: - Hardware Integration & Build (D15)
Task Leader: Partner 1 - AUTONUMIS

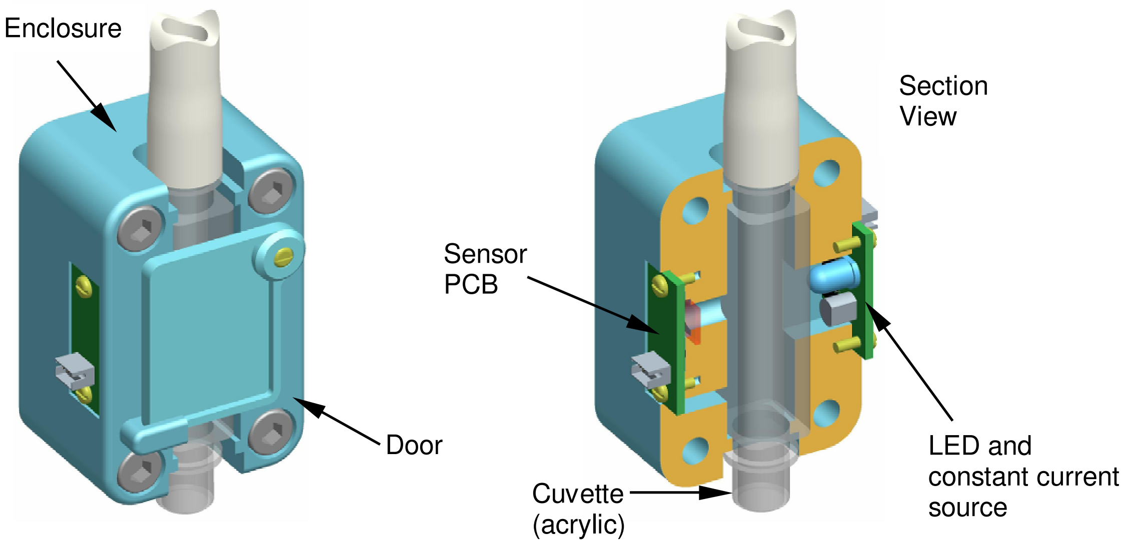
Objectives:
To design a fully integrated unit using test rig development information and designs from WP2, WP3 and WP4. Using 3D Computer Aided Design modelling tools to model the existing subsystems from work packages 2, 3 and 4; modify and reduce the sizes of the sub-systems for integration into the assemble. This will allow for the evaluation fit, function, weights and overall unit footprint prior to manufacture. Resulting in 2D assembly drawings, parts listings and detail drawings.

Costs for prototype production will be obtained from the CAD detail drawings. These will be used as a comparison against possible manufacturing costs for the end unit. Prototype parts list table with estimated parts and full unit costs. Including subsystem prototype manufacture to CAD designs.

Progress:
The primary systems that are being developed are modelled using 3D CAD, which include the juice concentration level absorption chamber and the mixing head. All of the individual component parts have been modelled and brought together as sub assemblies, which form the major systems. Each sub assembly has then been brought together to form one full system assembly, resulting in full parts listing for the machine.

Measurement Chamber:
The absorption chamber design was generated as shown below; this is based around three major components:

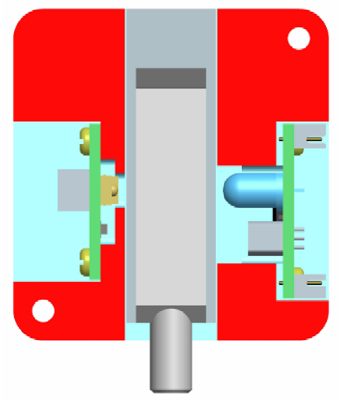
- Clear acrylic cuvette, through which the mixed juice will pass.
- Light Emitting Diode (LED), operating at 470nm, which emits a light through the cuvette and juice.
- Sensor, to measure the amount of light absorbed by the juice.



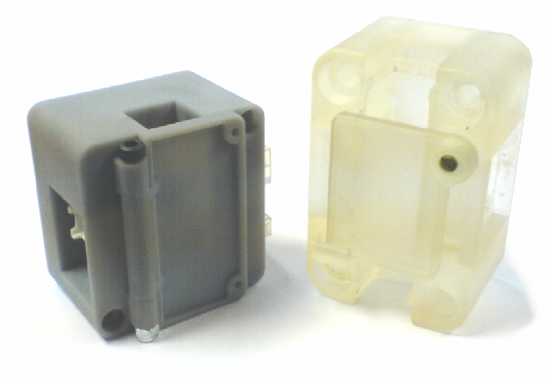
The electronics and cuvette have been mounted in an enclosure, which also acts to minimise the amount of ambient light that can reach the sensor and thus avoiding erroneous readings. To further reduce the risk of ambient light affecting the sensor readings, a light filter has also been used, placed directly in front of the sensor. The enclosure design has been optimised for manufacture by plastic injection moulding

Following initial tests the measurement chamber performed well, however it was felt by the consortium that the design needed further refinement to reduce the height of the chamber, which would offer the following benefits:

- Improved motor response – reducing the distance between the measurement point and the needle valve and thus reducing the response lag time.
- Reduction in the volume of liquid held in the chamber – this would lower the amount of water dispensed into the cup prior to dispensing concentrate.



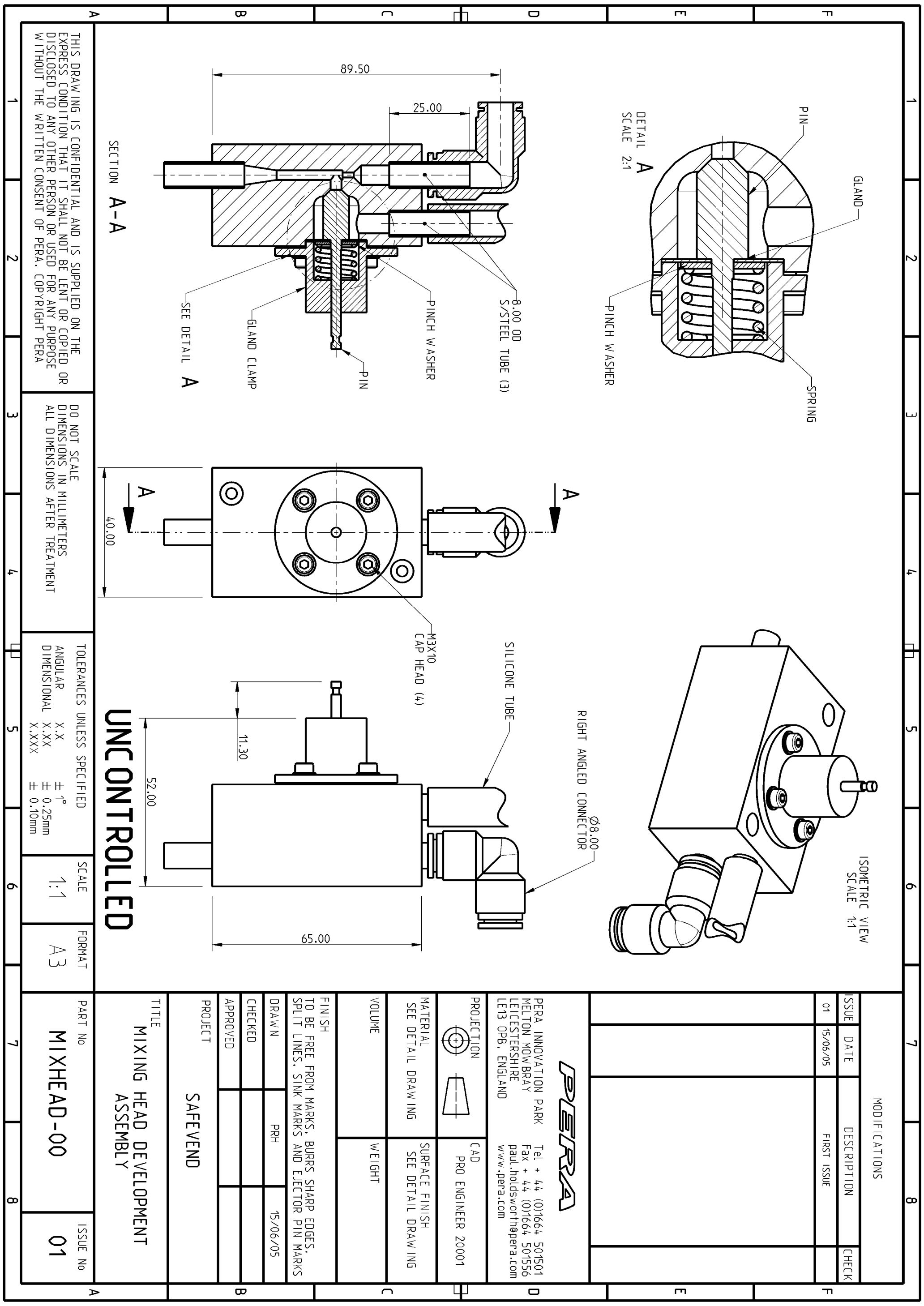
Absorption chamber cross section



Revised measurement chamber (left) Original chamber (right)

Mixing Head:

The mixing head is designed around the venturi principle, using the force of the incoming water to pull through the concentrate. The flow of the concentrate, and therefore the brix ratio, is controlled by a needle valve as shown in the CAD drawing below



Mixing head assembly drawing

The CAD data has now been turned into a prototype (see images below). This has been manufactured from clear acrylic, which allows for easy identification of a possibly contaminated system and to assess the concentre flow through the system.

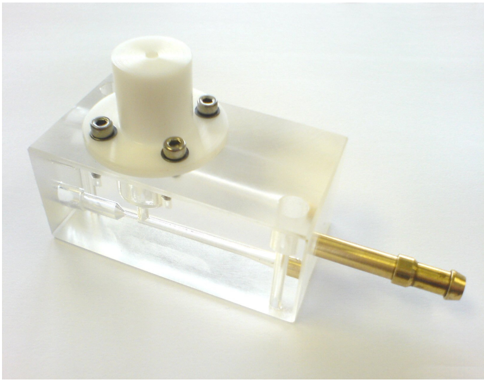
The mix head shown below performed well:

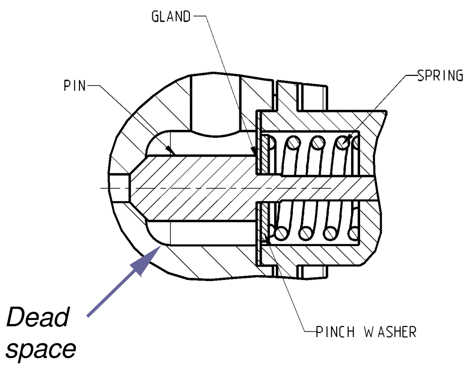
- Operating parameters – 1 litre per minute at 1.5 bar
- Delivering orange concentrate to maximum of 14.20 brix (required delivery 11.20 brix)

The mixing head performed extremely well under testing, with the water flow providing enough suction to pull through more than the required ration of concentre. However through hygiene testing, a problem area was identified. Whilst testing the mixing heads suitability for cleaning 'dead' spaces were identified.

In order to clean the system, it was decided that periodically clean water would be flushed through the head. When water was flushed through the reservoir the majority of the concentrate cleared very quickly, yet some residue did remain in the lower left corner of the reservoir. This area proved to be a 'dead' space where the water took the shortest route through the reservoir. This would also have implications upon the flow of concentrate under dispense conditions, whereby the concentrate would also take the shortest route thus leaving some concentrate standing in the dead space.

Acrylic Mix Head 01

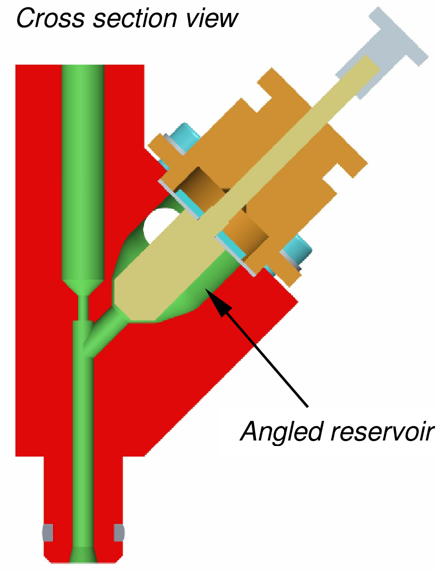


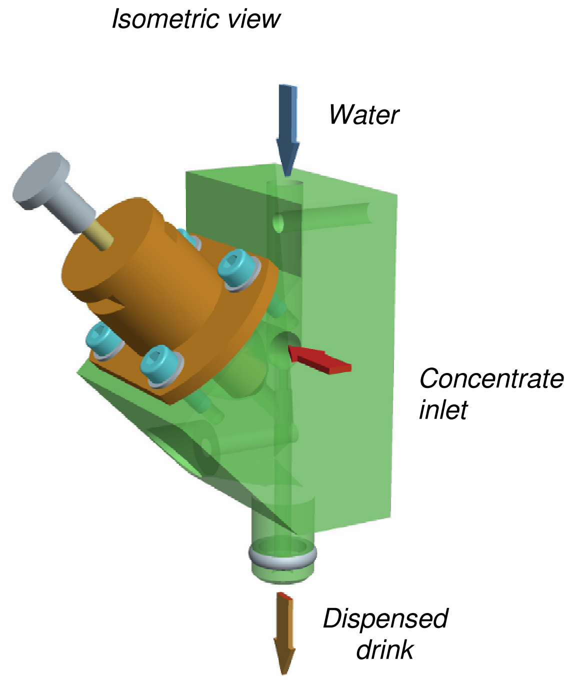


Reservoir detail

Revised Mix head:

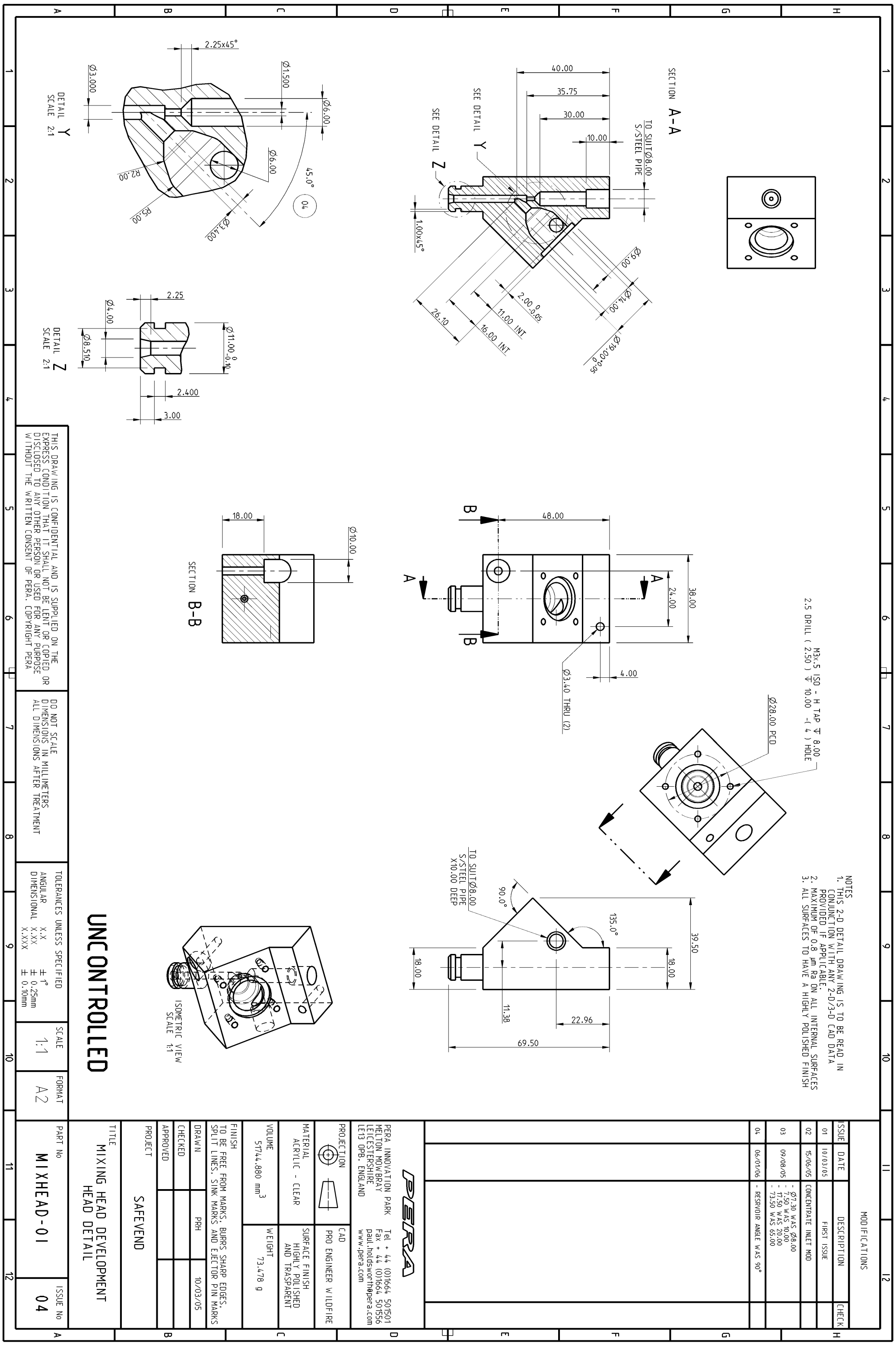
In order to improve the cleanability of the mix head it was decided change the orientation of the concentrate reservoir. On the original acrylic head the reservoir was perpendicular to the flow of water, the revised design placed the reservoir at an angle of 45 degrees, as is shown in the cross section view below.





Following the redesign of the mix head tests were performed to evaluate its performance. When compared to the previous design the head performed even better. With the 45-degree reservoir, and what is most probably gravity assist, is possible to dispense a drink to 16.62 brix, with the added bonus of improved cleaning and the removal of any 'dead' spaces.

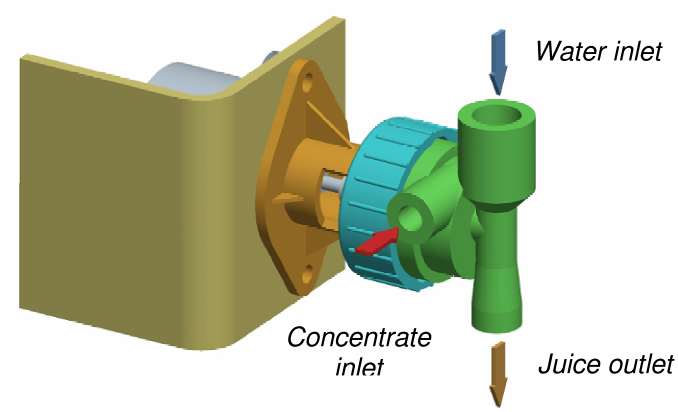
Acrylic prototype with angled reservoir



Mixing head detail drawing

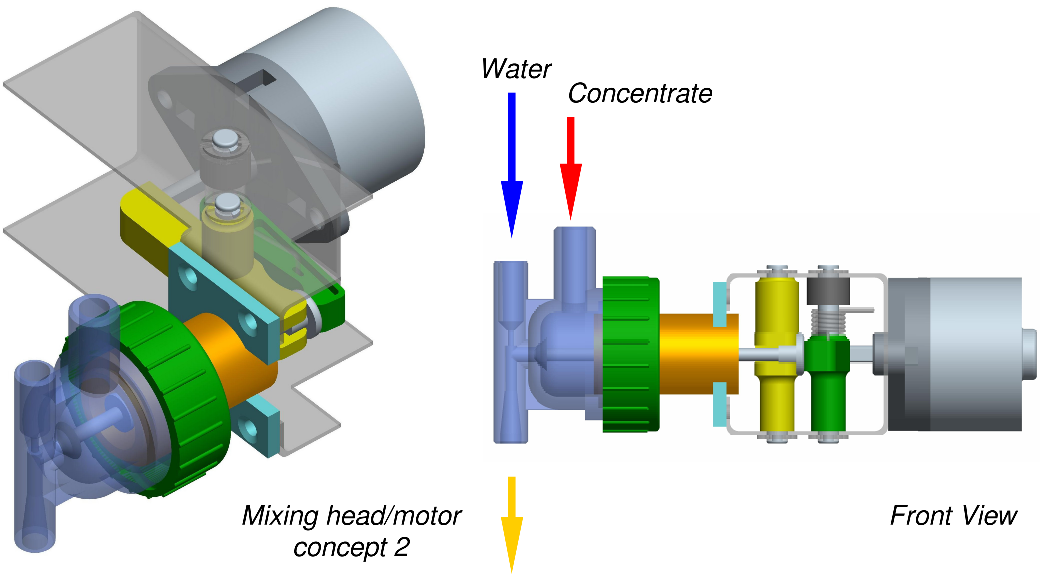
Production concept:

Following form the design of the venturi mixing head it was necessary to design a method of moving the needle valve, so it has an extremely fast response time but is also accurate. The first concept is shown below, whereby a stepper motor is used to move the pin in and out. This concept had two main problems; firstly the step interval was not fine enough to give an accurate adjustment of the amount of concentrate flowing through the venturi. Secondly the motor was permanently fixed to the mixing head and thus could not be removed for repair or cleaning.



Mixing head/motor concept 1

To answer the issues raised by concept one the design was revised, below, this time the motor was mounted off centre in relation to the needle valve. The motor now drove the valve by means of a pivot mechanism, by making the distance from the motor to the pivot greater than the distance from the needle valve to the pivot; it was possible to reduce the step interval seen at the valve.



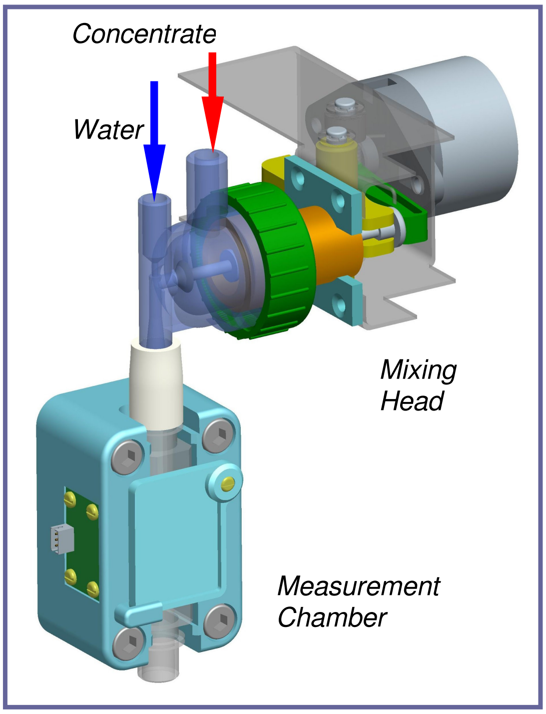
Mixing head/motor concept 2

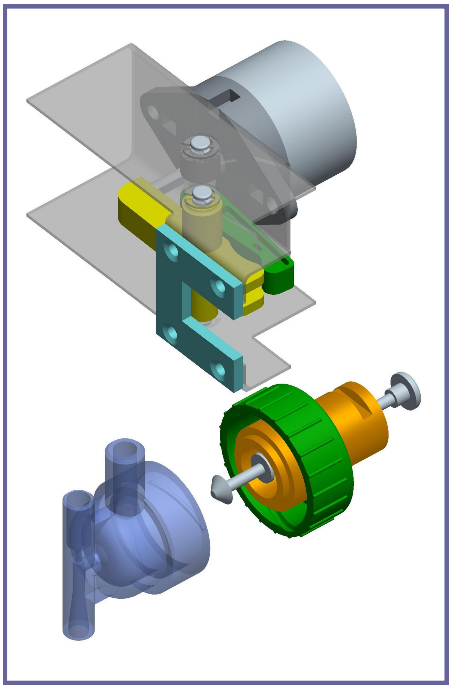
Front View

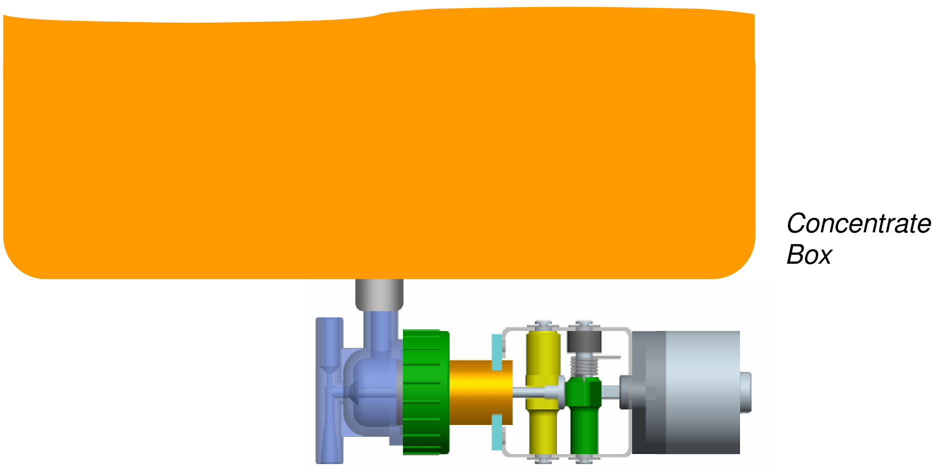
The use of the pivot mechanism also allowed for the design of a quick release mechanism, below, which allows for the mix head to be unclipped from the motor and then separated into two parts.

Sub-assembly integration:

The image below shows the combination of the mixing head and measurement chamber sub assemblies. The most important considerations are minimising the distance from the mixing head to the measurement chamber, to reduce the closed loop control response lag time, and the ease and simplicity of removing the separate units.

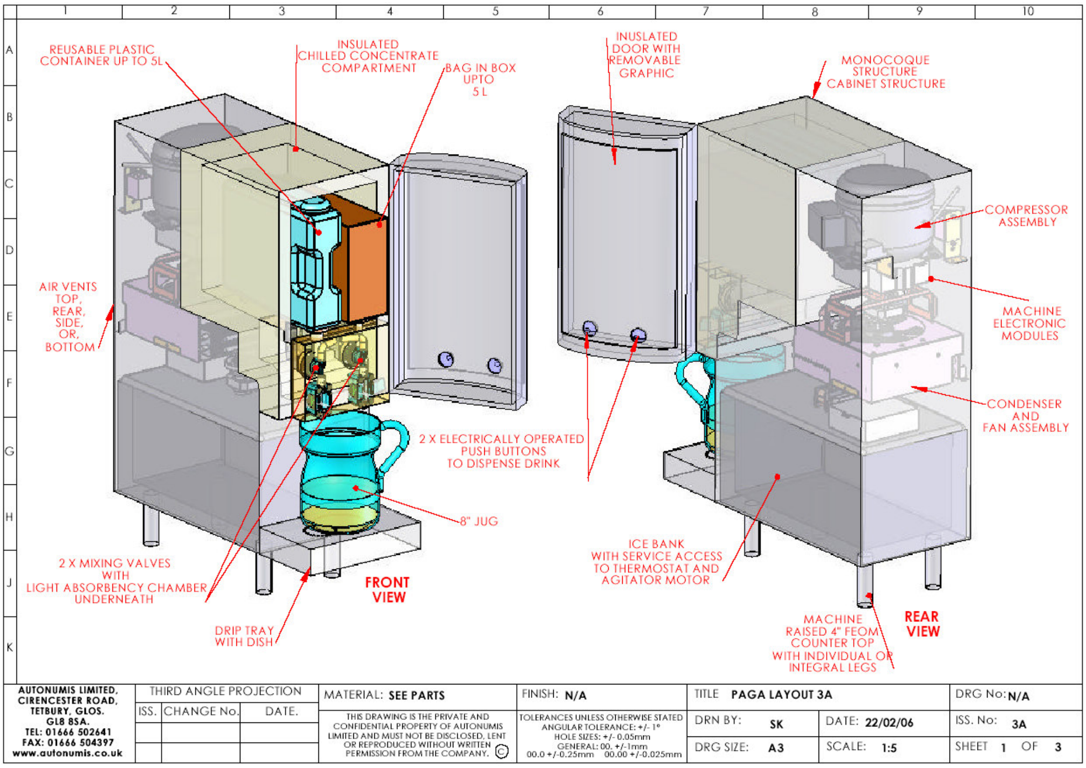






Full assembly integration:

As the separate sub systems have evolved and the designs become more concrete the detail have been brought together in a full 3D CAD assembly. This has enabled the critical factors such as the total footprint, height and width to be evaluated.



Based on the CAD models of the full assembly, and the experience of Autonumis in manufacturing dispensing machines, a prototype parts list table with estimated parts and full unit cost has been generated, below.

PA POST-MIX CHILLED DRINKS DISPENSER MATERIALS COST SUMMARY			DATE: 28/02/2006
NEW ITEMS			
ITEM	DESCRIPTION	QTY PER M/C	BOM COST
1	ICE BANK ASSEMBLY WITH LOW ENERGY COMPRESSOR AND CONDENSER FAN ASSY	1	£170.00
2	CABINET ASSEMBLY	1	£165.00
3	RFID ASSEMBLY INCLUDING TWO RECEIVERS	1	£20.00
4	LIGHT ABSORPTION CHAMBER ASSEMBLY MOULDING AND PCB	2	£25.00
5	MIXING CHAMBER INCLUDING STEPPER MOTOR	2	£40.00
6	PUSH BUTTON USER INTERFACE ASSEMBLY	2	£20.00
7	CONTROL PCB ASSEMBLY	1	£50.00
		TOTAL ESTIMATED MATERIALS COST	£490.00 (€717.00)

Task 5.2: - Integrated Prototype Assembly (D16)
Task Leader: Partner 1 - AUTONUMIS

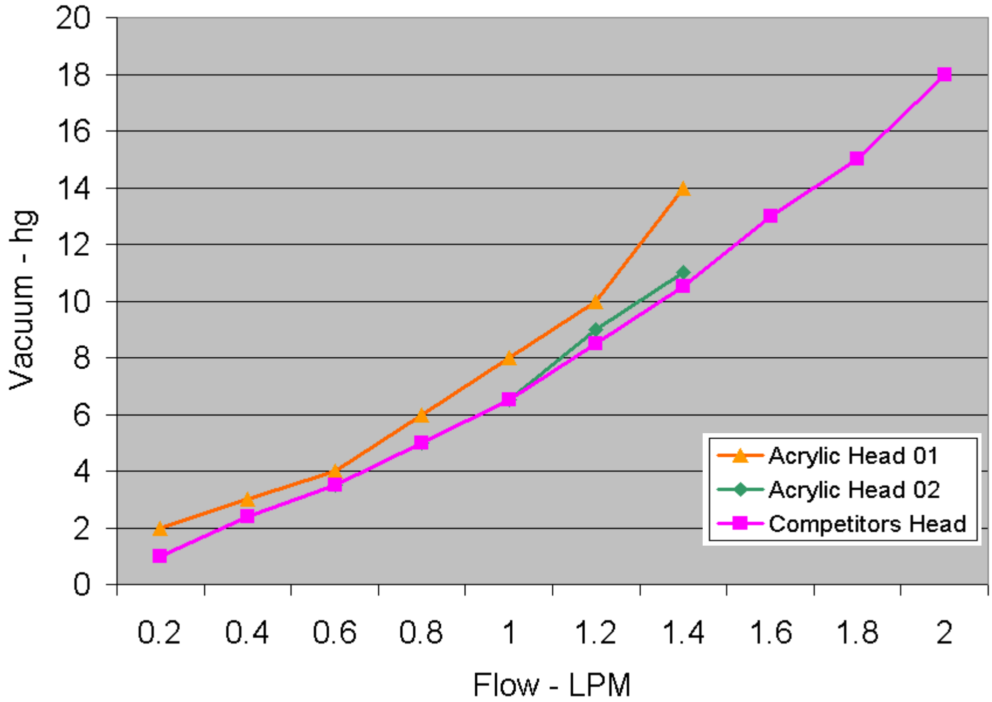
Objectives:

- Testing of individual subsystems, and comparison with the work packages original data, to ensure correct performance prior to full assembly.
- Table of subsystem trial data and comparison of refractometer system (WP1 and WP2).
- Mix control valves and mixing system (WP2).
- FPSC, heat exchange and storage systems (WP3).
- Steam generation system (WP3 and WP4).
- Subsystems integration resulting in one fully assembled vending unit with full mechanical parts integration.

Progress:

Mixing head testing and further development:

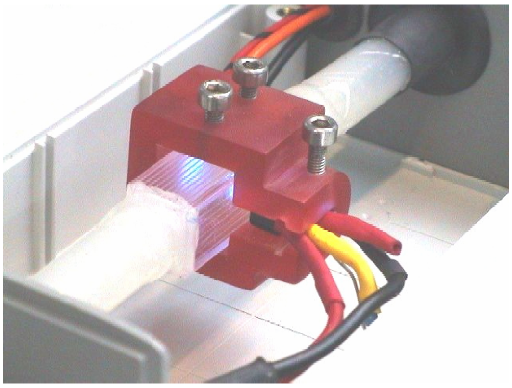
Following on from the development work carried out on the mixing head development, in task 5.1, the performance of the new design was tested against what is deemed to be the leading competitors. The graph below shows the increased performance, in terms of vacuum generated to pull through the concentrate, of the mixing head developed under the Safevend project.



The vacuum tests were performed using mains water at a pressure of 1.5 bar, a typical minimum requirement for dispensing machines. Tests were then conducted on orange concentrate. These showed that it was possible to draw through enough concentrate to dispense a drink of to a value of 14.20 brix for head 01 and 16.62 brix for head 02, whereas the standard brix value for orange is 11.2.

Light absorption chamber:

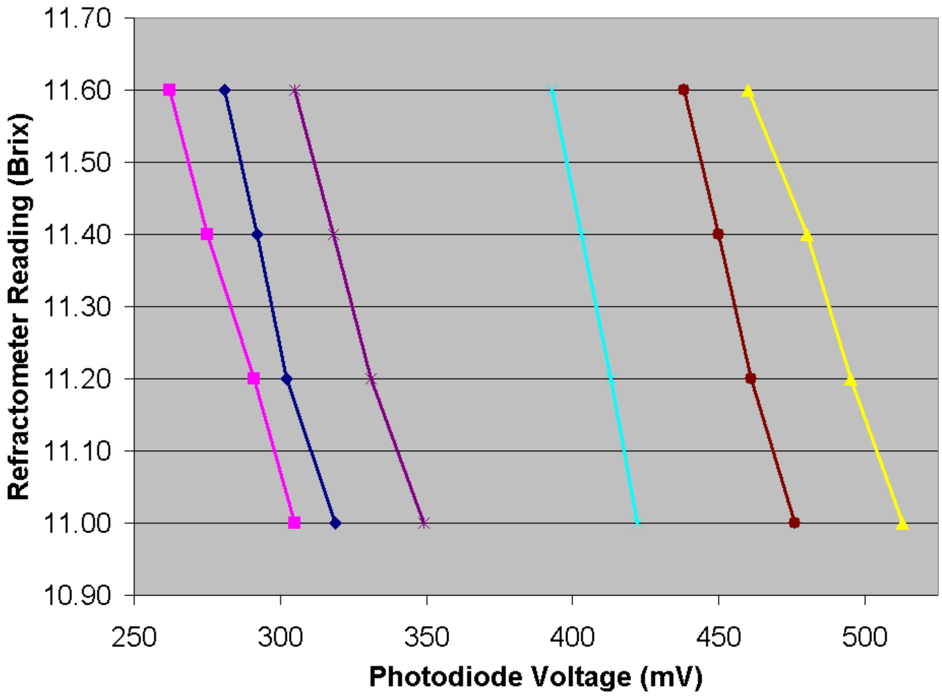
Further testing has been carried out on the light absorption chamber, to establish absorption characteristics of geographically diverse fruit concentrates. The aim of this trial was to establish if a generic concentre, in this case orange, could be identified. Or if each geographically different orange concentrate had its own individual signature.



Light Absorption Chamber

LED 470nm L-7113PCB
Photodiode TSL250R

The graph below shows the comparative absorption results versus the refractive index. The graph illustrates that each concentrate do have individual absorption characteristics. But each of the trend lines is reasonably linear and shows similar characteristics to the other samples tested; this highlights a consistency in the absorption characteristics.



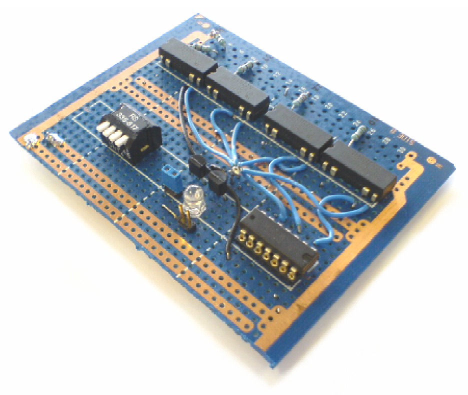
Absorption chamber electronics design:
In order to be able to measure the absorption characteristics of all fruit juices it was important to establish a method of controlling, extremely accurately, the output from the LED. This was necessary because the range of juices is diverse, orange is typically extremely opaque, whereas apple is translucent. Therefore an LED setting that transmits through orange and gives a useable reading form the photodiode would saturate the same photodiode when transmitting through apple.

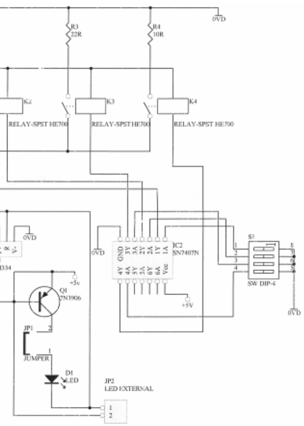
To solve this problem a constant current board was developed, with the help of BCN, this uses 4 resistors to control the current to the LED. By utilising the 4 resistors in different combinations it is possible to switch the LED output through 15 varying settings.

Constant current board:

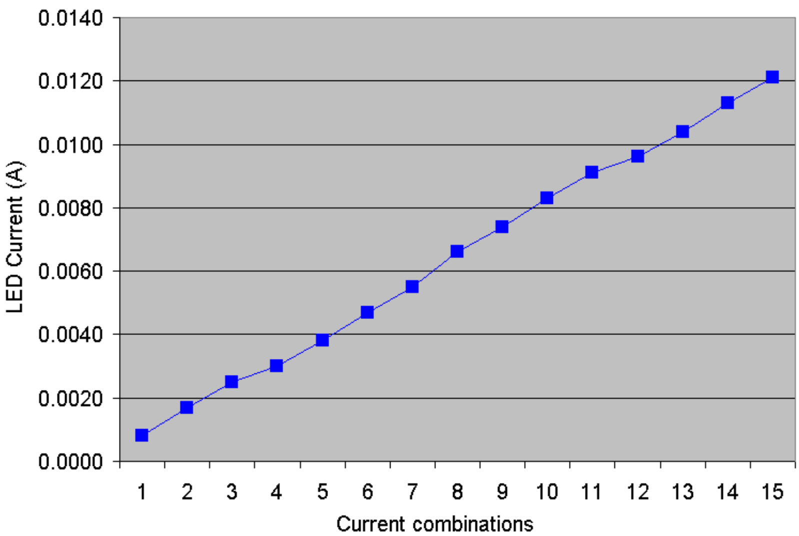
- 4 resistors = 15 current combinations (0.8-12.1mA)
- Maximum current draw of 70mA with all 4 relays turned on

Initial prototype test board





Circuit layout

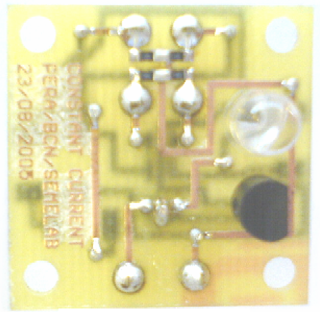


LED output

Absorption chamber electronics miniaturisation:

Following the successful trials of the LED control electronics the next stage was to reduce the size to for integration within the measurement chamber. The images below show the detector, comprising of a photodiode and amplifier and the transmitter, a scaled down version of the constant current board previously described.

Detector



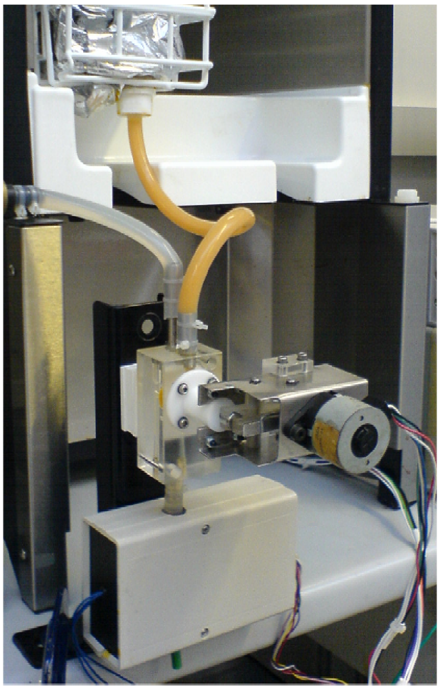
Transmitter

Around the two prototype circuit boards (PCB's) a plastic enclosure was design. The purpose of the enclosure was to hold the PCB's n

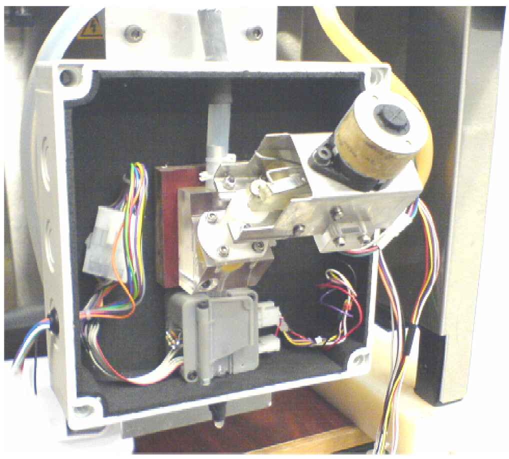
Mixing/measurement chamber:

Through work conducted in task 5.4, testing and technical validation, it became evident that the system was susceptible to light ingress, though the acrylic mixing head. A certain amount of light reflection was also evident within the measurement chamber. To remove any ambient light contamination both the mixing head and measurement chamber were placed in an enclosure. The internal surface of the enclosure were coated in neoprene foam to reduce light reflection form the LED.

Original mix/measurement chamber



Lightproof enclosure



Box identification:
A system has been identified that can recognize the concentrate being used within the machine. This system will link with the concentrate level settings and prevent counterfeit products from being used and notify the machine of the correct absorption/brix settings required.

Various systems were evaluated such as barcode labelling EMID (Electro Magnetic Identification) and RFID (Radio Frequency Identification). RFID proved to be the most suitable and flexible system, a summary of the details are below:

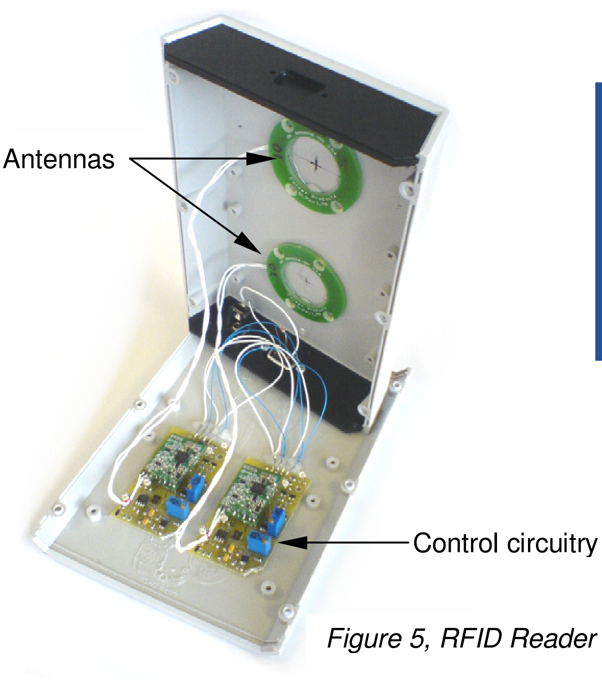
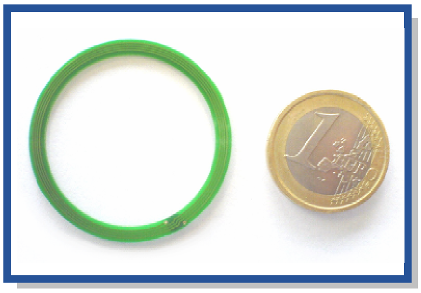


Figure 5, RFID Reader



RFID Tag

Approx costs:

- Reader - £5 to £10
- Tag – 10p to 15p (not hugely volume dependent)

Advantages:

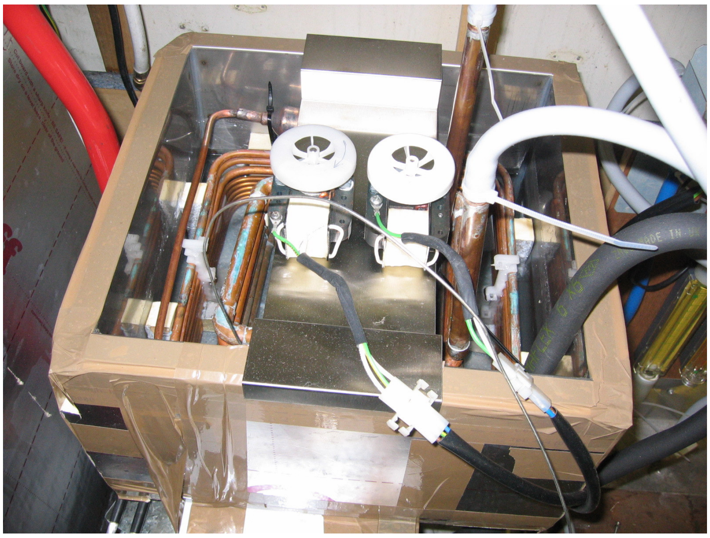
- Low cost of reader
- Can read and write to tag (up to 96 bytes of data on a tag)
- Will allow the box to be removed and returned to the machine
- Will allow the tag/box to be cancelled without a unique identifier
- Tag can be concealed within the box to protect it
- Accurate positioning to the reader not necessary (approx 30mm)
- Possibly use an existing off the shelf tag and reader system
- Able to buy blank tags and add data easily at packers
- Proven technology

Disadvantages:

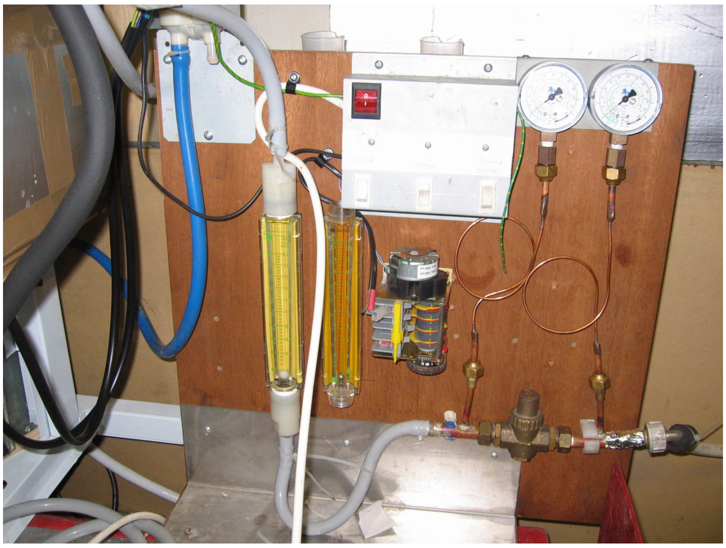
- High (relatively) cost of tag
- Very high cost of development if bespoke tag and reader
- (£50k for reader and tag, £10k for tag)

Water cooler:

To facilitate the rapid dispense rate of 60litres per hour at a temperature of around 5ºC it was necessary to devise a cooling reservoir. The reservoir was designed around the principles of phase change materials (PCMs), water proved to be the most efficient PCM for storing cold energy. The images below show the prototype for the reservoir, which consists of a copper coil taken from the cooling system and a copper coil containing drinking water both of which are submerged in a bath of water. The reservoir is used to store the cold energy produced by the cooling system and acts as a heat exchanger, which in turn cools the drinking water



Cold water bath



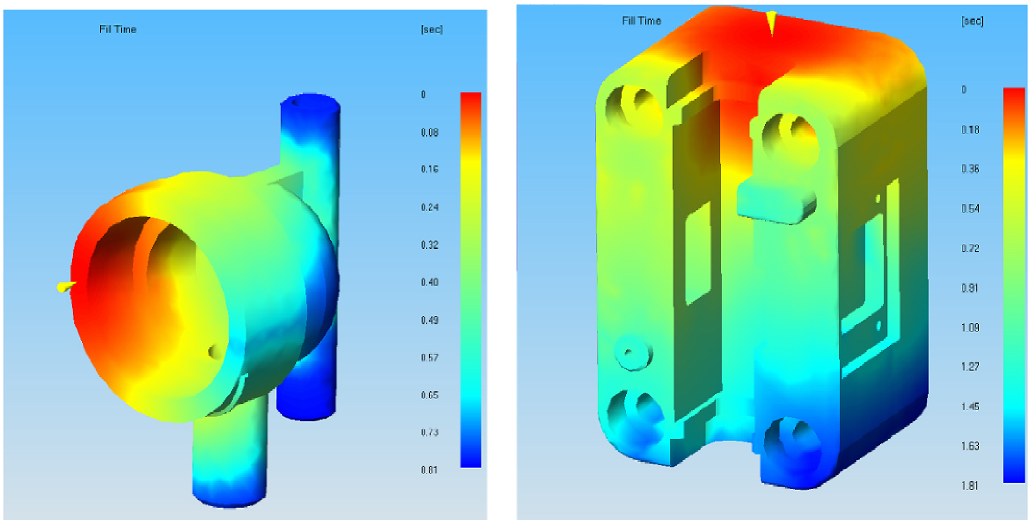
Test Apparatus

Testing of component manufacturing suitability:
In order to assess the prototype designs suitability, for eventual production application, it was necessary to analyse the 3D Computer Aided Design (CAD) models. The analysis took the form of plastic injection moulding flow simulation, using a package called Moldflow™.

The flow simulation allowed us to determine the manufacturability of mix head and measurement chamber during the preliminary design stages and avoid potential downstream problems, which can lead to delays and cost overruns. This analysis allowed:

- Optimize the part wall thickness to achieve uniform filling patterns, minimum cycle time and lowest part cost Identify and eliminate cosmetic issues such as sink marks, weld lines and air traps.
- Determine the best injection locations for a given part design

Moldflow analysis showing fill time and injection points



Task 5.3 – Closed Loop Control Integration (17)
Task Leader: Partner 1 - AUTONUMIS

Objectives:

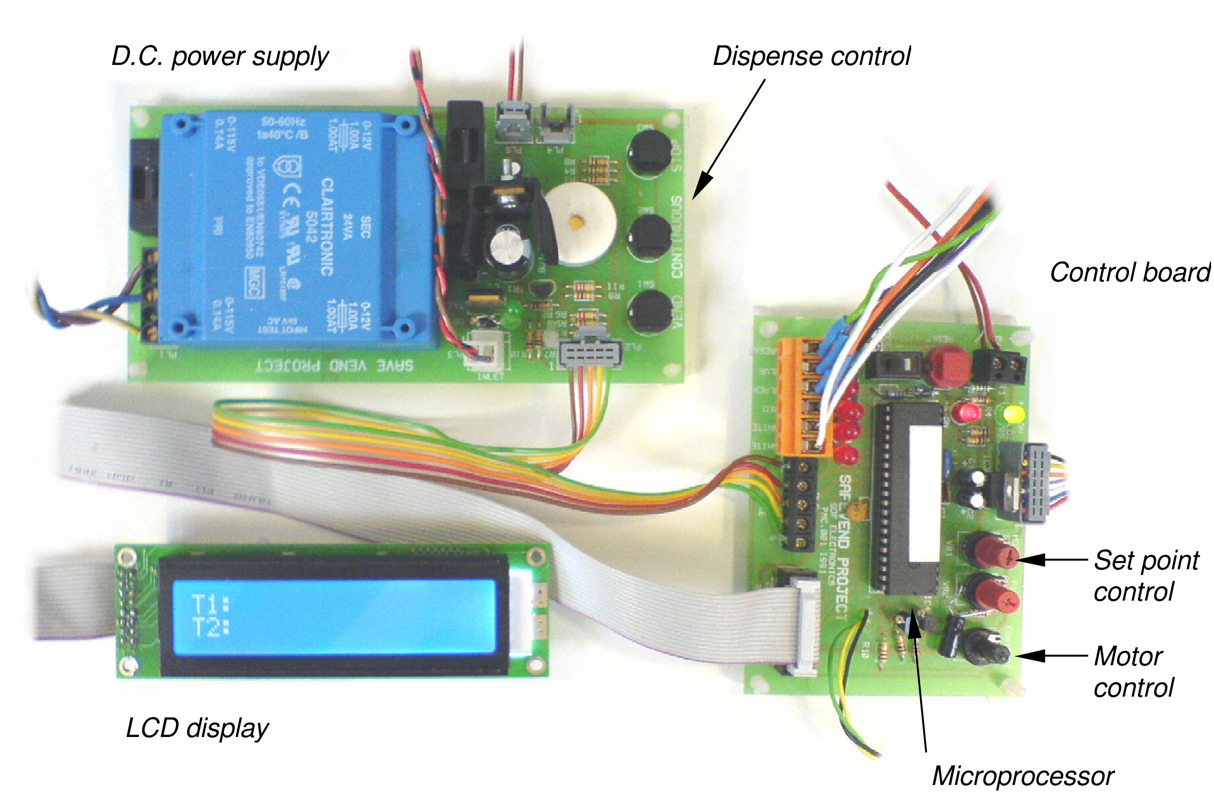
The combination of the separate subsystem control systems and algorithms into a top level electronic control board and microprocessor to:

- Receive data from the refractometer (wp2) and temperature sensors (wp2) and compare this information with the brix knowledge database (wp1) using the control algorithm (wp2).
- Alterations to the mix valve ratios (wp2).
- FPSC modulatory control from temperature inputs (wp3).
- Establish an optimal cleaning regime algorithm using number of drinks dispensed sensor information in association with ambient temperature sensors microbial contamination growth database (wp1).
- Identify acceptable cleaning period using system usage monitoring algorithms to identify quiet periods of time (wp4).
- Activate cleaning cycle, steam temperature monitoring and activation (wp3 and wp4).

Progress:

Central control system:

In bringing together the separate mechanical and electronic subsystems, for the Safevend machine, it was essential to design and manufacture a central control system. The prototype circuit boards, below illustrate the components within this system:



At the heart of the unit is the microprocessor, each of the individual subsystems has an input/output connection to the microprocessor and the assembly code within the processor controls all operations. The microprocessor has been specified so that it has enough input/output pins to allow for the systems below plus additional connections.

- Mode switch
- Reset switch
- Dispense control
    - Measured
    - Continuous
    - Learnt
- Radio Frequency Indent Tag
    - Data read from tag
    - Data written to tag
- Measurement chamber
    - LED current control and temperature compensation
    - Photodiode amplification gain
- Mix head – current amplifier and stepper motor control
- Mix head – gain (overshoot/response) manual control
- Set point manual input
- Dispense/solenoid control
    - Vend – learning option
    - Continuous vend
    - Stop
- Cooling system control
- Cleaning system control
- Liquid crystal display – used for
    - RFID information
    - Volume dispensed
    - Cooling system temperature set and display
    - Photodiode - set point for required concentration level
    - Photodiode - actual set point measured
    - Stepper motor - position
    - Stepper motor - stepping period
    - Stepper motor - gain (overshoot/response)

Liquid Crystal Display:

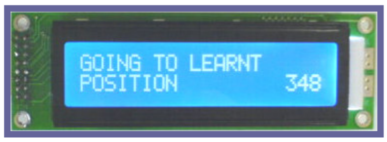
The LCD provides an essential link in manually programming the system and providing verification of the performance of the mix head and measurement chamber.

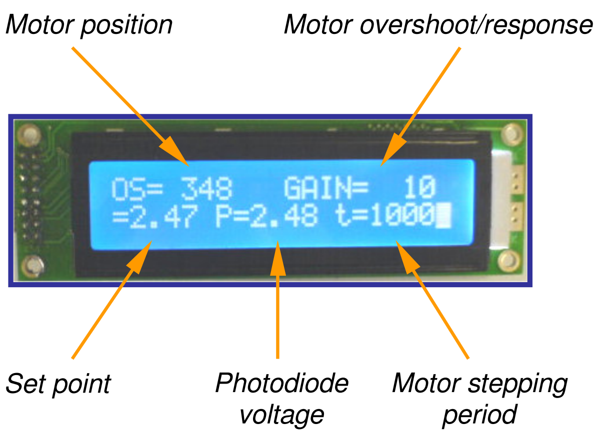
A novel operation performed by the processor is to ‘learn’ the optimum position, for the stepper motor and thus the needle valve, to dispense a drink to the required set point.

This operation improves quality of the drink dispensed, especially when only a small volume is required. When a ‘new drink’ is dispensed the motor moves to the learnt position. This removes the need for a response to be received form the photodiode, relating to the concentration level of the dispensed liquid. The photodiode output would most probably be inaccurate, as when the needle valve is opened a few milliseconds pass before for the concentrate is drawn through the venturi and into the measurement chamber. Therefore during the initial stages the photodiode output would be inaccurate, relative to the position of the needle valve.

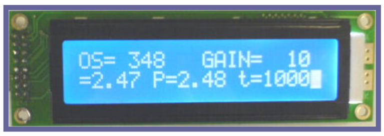
This process is illustrated below by the information displayed on the LCD:

1. New drink





2. Dispensing



3. Finish

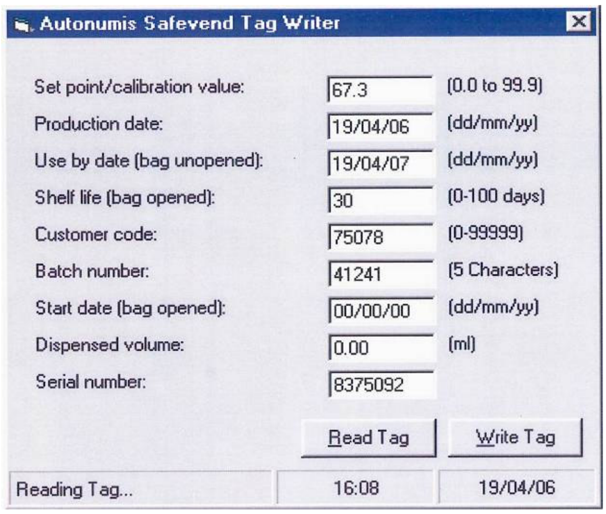
RFID Interface:

Integral to the whole Safevend machine is the Radio Frequency Identification, as developed in task 5.2. As the fruit concentrate is packaged the RFID tag will be bonded to the container, information specific to the concentrate will then be written to the tag as outlined below:

- RFID tag information capacity - 96 bytes
    - 8 are used for the serial number, 8 are for access codes
    - Resulting in 80 bytes.
    - Safevend requirement less than 48 bytes
- Set point - 3 digits – photodiode voltage
- LED output value - 4 digits - tells the machine how much light the LED needs to emit for the given product
- Production date - written to the tag by the packers
- Use by date, unopened - written to the tag by the packers
- Shelf life, once opened - 3 digits (i.e. number of days) - written to the tag by the packers
- Customer code - 3 digits - contains a reference number that enables the machine to distinguish between correct
- Batch number - 6 digits - written to the tag by the packers
- Box start state - date when the box is first put into the machine, written to the tag by the machine
- Dispensed volume - 5 digits - the amount (ml) that has been dispensed

Once the concentrate is placed into the dispensing machine the RFID information is read, which is used to verify that an approved manufacturer has supplied the product and it is within use by dates, this control system ensure that the concentrate meets quality and hygiene standards. Information specific to the type of concentrate is then used to establish the dispense settings so that a consistent and quality product is dispensed.

The illustration below sows the concept interface for the concentrate packer, this information will be written to each RFID tag as the concentrate is packed

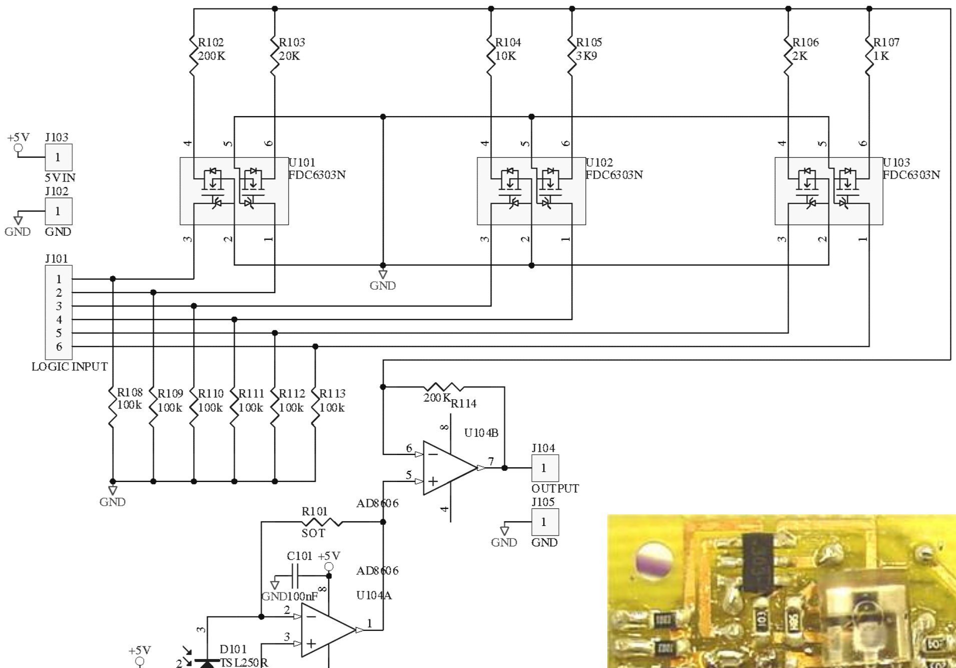


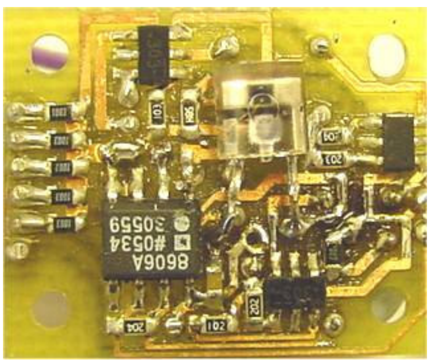
Calibration routine:
During task 5.4 tests were performed on the quality of the dispensed drink in relation to the brix level. The tests were carried out using orange concentrate, which should be dispensed to 11.20 brix and to a tolerance of +/- 0.20, as stated in the Safevend proposal. The results of the brix dispense tests, see task 5.4, were extremely good, and during 22 dispensed drinks 19 were within tolerance. However the drinks towards the end of a dispense began to show a consistent drift out of tolerance.

Through further testing it was established that, over time, the Photodiode and LED performance did alter slightly. Indeed all of the components on the LED and photodiode PCB's operate within certain tolerance bands, which results in an incremental tolerance greater than that of the individual components.

To overcome this problem a calibration circuit was designed for the photodiode PCB. Before each drink is dispensed a microprocessor would perform a calibration routine, through water, by modifying the output from the LED and reading the response from the photodiode any deviation in readings could be compensated for. The diagram below shows the diagram of the calibration circuit and the prototype board.

Calibration circuit





Prototype photodiode board with external amplification circuit

Calibrated Mixing:

The board has two modes selected by the MODE slide switch.

1. Juice set point calibration mode.

   a. Display shows 'Place water & press Vend'.
   - A cuvette of water is placed in the holder.
   - Vend is pressed.

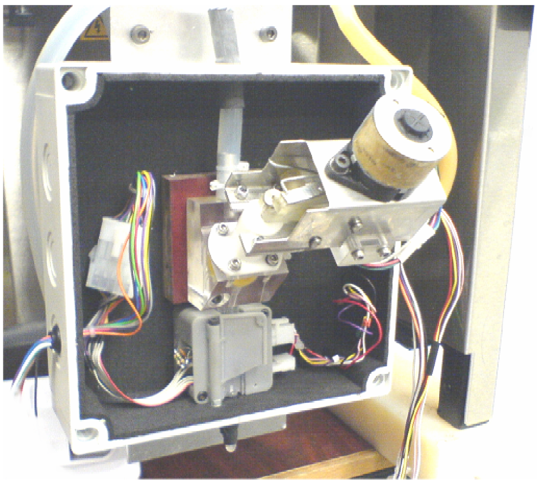
   b. The photodiode amplifier gain is set to 1.
   - The board steps down the led current from maximum until the photodiode a/d reading < 819. This is an arbitrary value corresponding to about 4.0V, which is a high value safely below saturation.
   - The actual value does not matter as the juice measurement will be made at the same LED current, and it is the ratio of a/d readings, which matters.
   - The actual a/d reading at this current is recorded.

   c. Display shows 'Place Juice & press vend'.
   - A cuvette of juice is put in.
   - Vend is pressed.

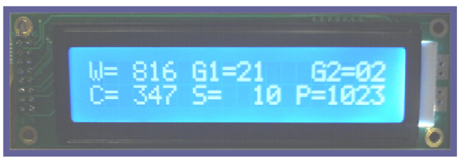
   d. The photodiode amplifier gain is stepped down from maximum until a/d <819, again a high figure safely below saturation.
   - The actual a/d reading and gain are recorded.

   e. The calibration factor is calculated:
   - CAL = (Water A/D x Gain x 10) div (Juice A/D)
   - The x 10 is added to keep the numbers large and avoid losing accuracy in the division as integer calculations are used.
   - The result is a figure corresponding to how much more light passes through the water than the juice multiplied by 10.
   - A typical figure of CAL=258 meaning the ratio is 25.8 for our orange juice sample

   f. The display shows the measurements and calculation result, eg.
   - WATER=786   GAIN=21
   - JUICE=639   CAL=258



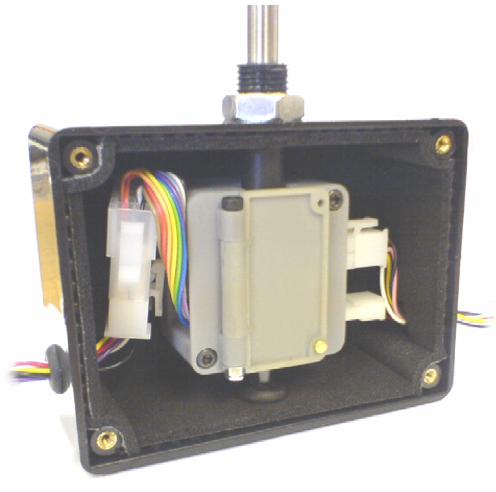
Mixing head and measurement chamber



LCD display of calculations

2. Mixing Mode.

a. The inlet valve opens.
b. The LED nominal current is set and the photodiode a/d recorded as in (b) above.
c. The photo diode gain is set to the nearest possible setting below CAL/10. This will probably happen to be the same gain setting as was used in the original calibration, but it needn't be as long as the gain value is accurate.
d. The expected a/d reading for the correctly diluted juice is calculated:
   - Juice A/D = (Water A/D x Gain x10) div CAL
e. The mixing head moves to the last learnt value (or default if none), and the board attempts to regulate the photodiode A/D reading to the required value.
f. While vending the display shows:
   - W=water A/D
   - G1=photodiode amp gain
   - G2=closed loop gain
   - C=calibration value
   - S=calculated set point (juice a/d)
   - P=actual current photodiode a/d reading
g. At the end of the vend any new learnt value is saved, the head closes and the inlet is closed.



Mixing head and measurement chamber

Task 5.4 – Test and Technical Validation (18)
Task Leader: Partner 1 - AUTONUMIS

Objectives:

The objectives of this task are to assess the supervisory system implementation and testing, performing laboratory functional trials using the integrated prototype. Operation trials under taken, to assess:

- Continuous and sporadic performance
- Reliability
- Accuracy and repeatability
- Cleaning period suitability.

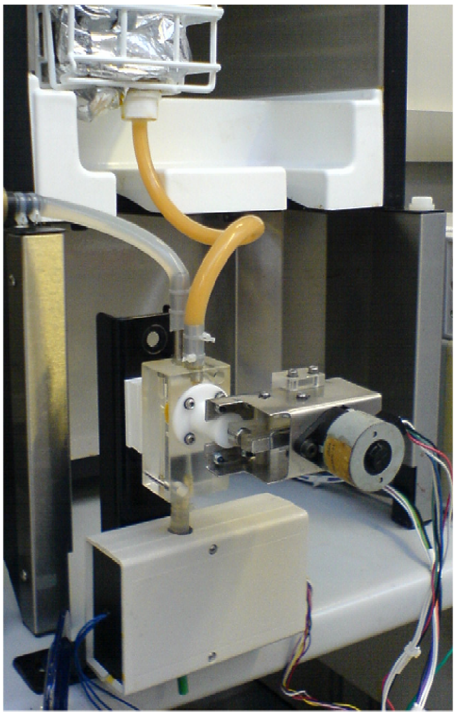
Progress:

The main focus of this task was the testing and validation of the dispensing and measurement mechanisms. Mainly concentrating on evaluating and refining the measurement chamber and mixing head.

Brix dispense tests:

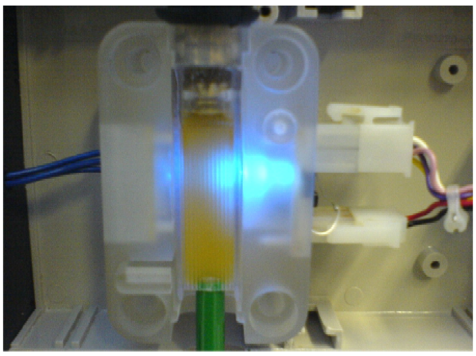
Initial evaluation testing was carried out using orange concentrate, as this is typically the most viscous and opaque liquid, which would be dispensed in the final machine. Therefore it was decided, by the consortium, that orange would be the most difficult concentrate to both dispense and measure.

The images below show the test rig used to perform the first tests, this consisted of the clear acrylic mixing head and the measurement chamber, enclosed in a light proof plastic box.



Mix head and measurement chamber

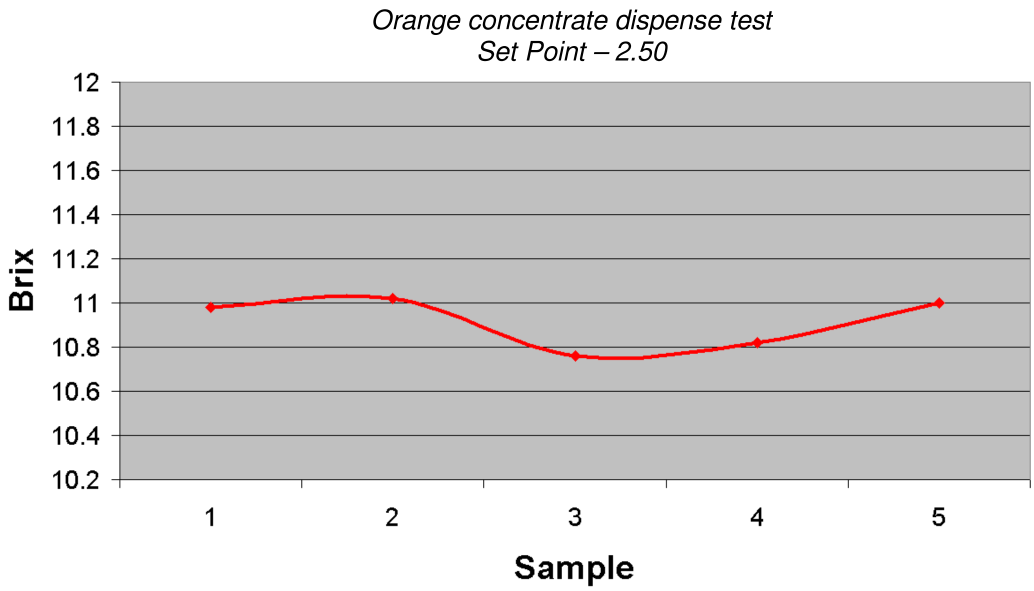
Measurement chamber internal detail



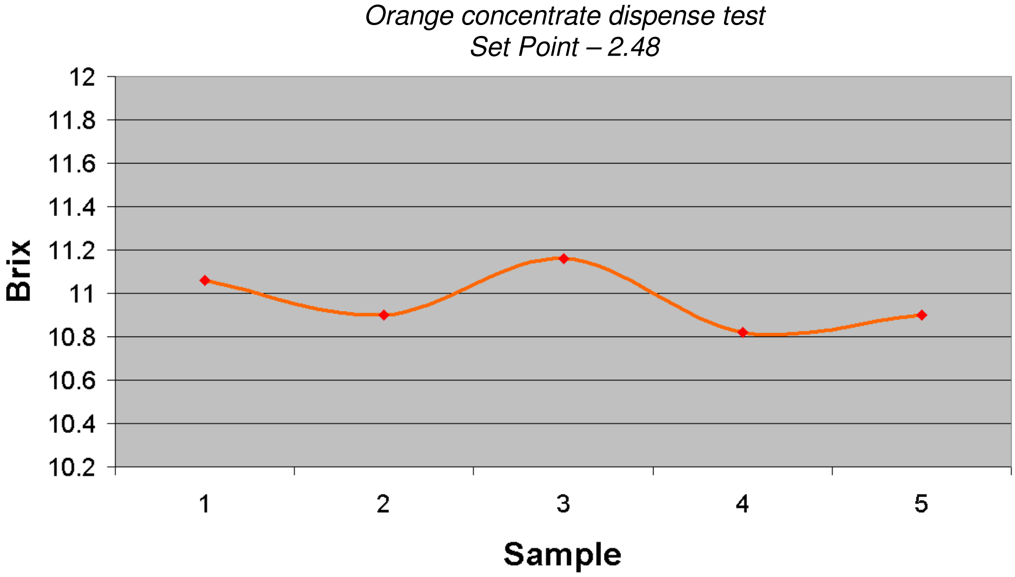
The dispensing system operates using a venturi mixing head, which utilises the incoming mains water, restricted to 1 litre per minuet and 1.5 bar, to pull through the concentrate. The mixed concentrate and water then flows into a cuvette within the measurement chamber. Whilst the mixed concentrate and water passes through the cuvette an LED is transmits light through the solution, which is picked up by a photodiode. The light captured by the photodiode is then converted to a voltage.

The amount of light that passes through the liquid directly relates to the ratio of concentrate to water. Prior to the dispense, of a drink, a set point is manually input, this relates to the photodiode voltage output. Dependent on the output form the photodiode the position of the needle valve, in the mixing head, is modified to allow more or less concentrate through the system. This process attempts to produce a drink that generates a photodiode voltage equal to the set point.

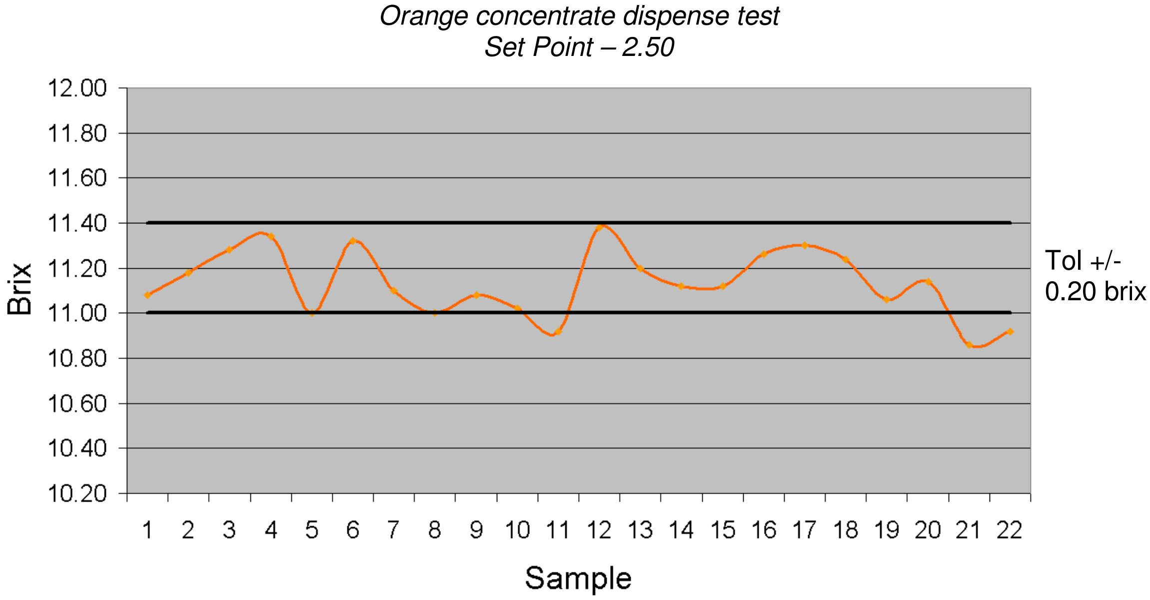
The graphs below show the initial tests, performed on orange concentrate, to determine the repeatability of the dispensed liquid relative to the desired brix values. The set point, for the desired concentrate dispense, relates to the output form the photodiode. This can be seen from the graph below, an output of 2.50 volts will give a drink with a brix value of between 10.76 and 11.02.



The affect of raising the desired set point is to increase concentration of the dispensed liquid. More concentrate is released into the water flow, which in turn obscures the light from the LED thus reducing the output form the photodiode. The following graph illustrates this principle. The reduced set point of 2.48 volts had resulted in a more concentrated dispensed drink, with brix values of between 10.82 and 11.16.



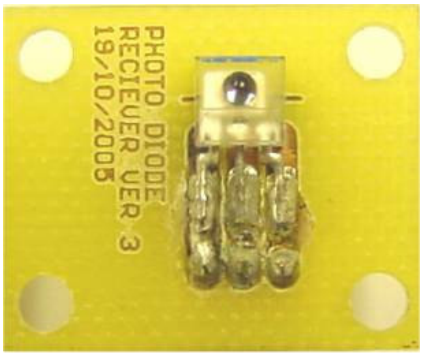
Once the set point had been identified, which would dispense a drink of orange to the ideal brix level of 11.20, a series of dispense consistency tests were performed. The graph below shows the progression through 22 individual dispenses. The initial proposal outlined a target dispense of +/- 0.20 brix, this would necessitate a dispense of between 11.00 and 11.20 brix, indicated by the two tolerance bands on the graph.



The initial results were very positive, with only three of the 22 dispenses falling outside the tolerance bands. However as the tests progressed it became evident that over time the concentration of the drink did fall. Through testing and validation it became evident that both the photodiode, LED and electronic components within the measurement device operate within a tolerance band and their values can drift over time. To overcome this problem additional development work was undertaken, focusing on the photodiode side of the measurement chamber.

The original photodiode board was extremely simple with one component, a hybrid photodiode, which had an inbuilt amplification circuit. The new PCB now had a basic photodiode, made up from a small piece of silicon and a lens, but now had an external amplification circuit that could be tuned to remove any tolerance deviation generated by the photodiode, LED or any additional components.

Original photodiode

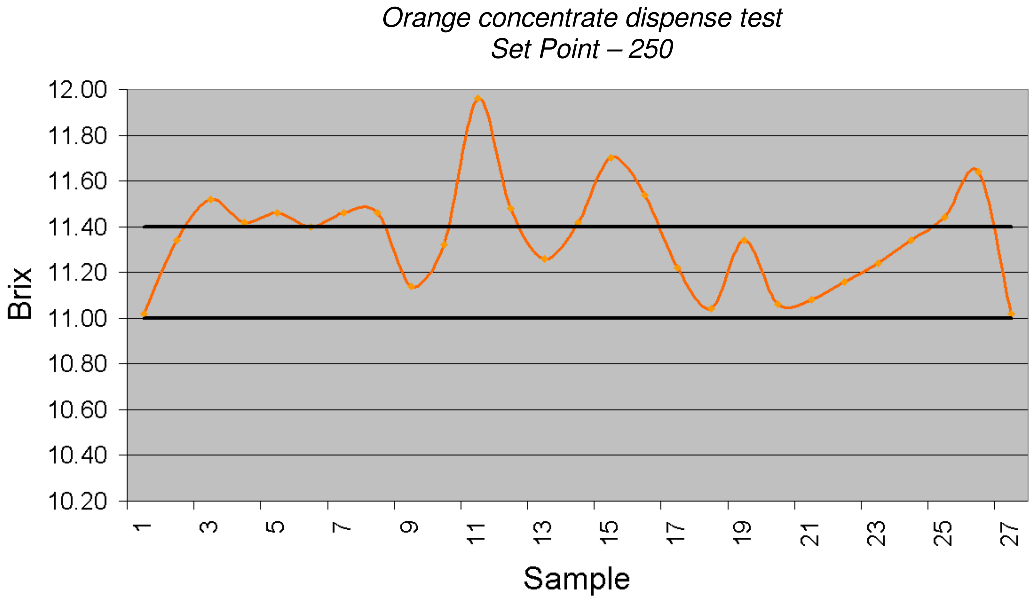


Revised photodiode

The calibration routine operates prior to the dispense of each drink and takes only a fraction of a second. As each drink is dispensed the mixing chamber repeatedly fills and empties. In order to ensure the chamber is kept in the best condition, to avoid bacteriological problems, a small shot of clean water is let through after the last measure of concentrate is metered in. The small water flush has the consequence of diluting the finished drink slightly so to compensate for this the software of the measurement device meters in slightly more concentrate.

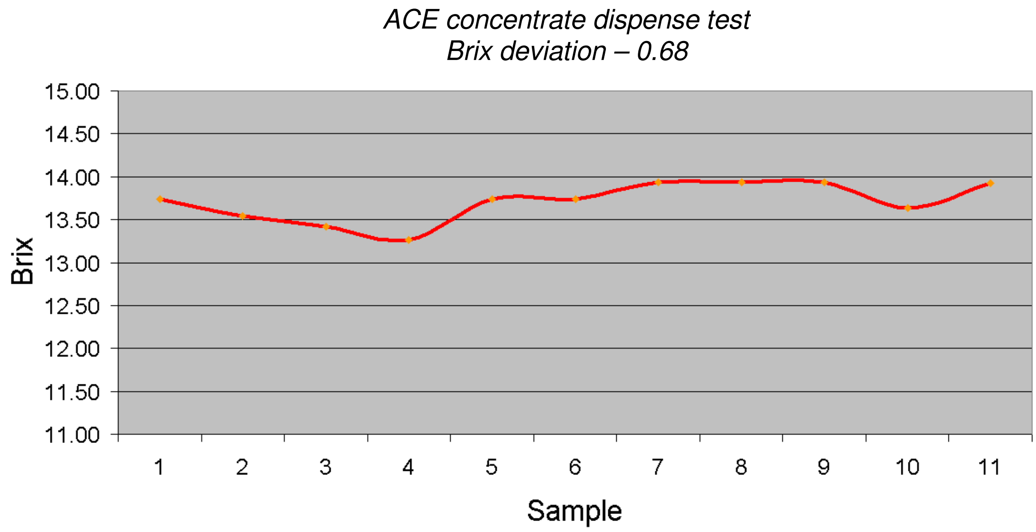
Following the development of the calibration circuit, the performance trials were repeated with a number of differing concentrates and the system refined.

The first set of tests, shown in the graph below, did not provide a consistent dispense. The metering head was attempting to control the amount of concentrate flowing into the system, however the new photodiode did not prove to be as sensitive to light transmission as the hybrid photodiode.

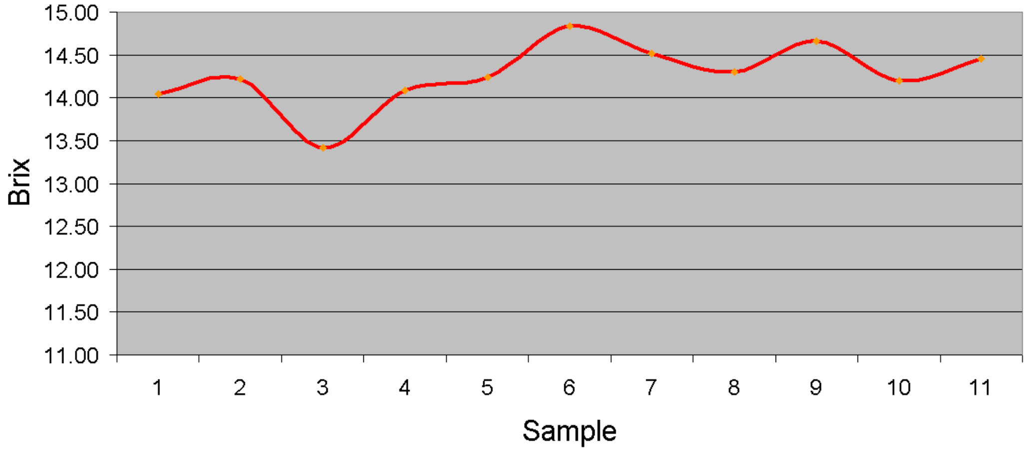


Further tests were carried out using the following fruit concentrates, whilst refining the system:

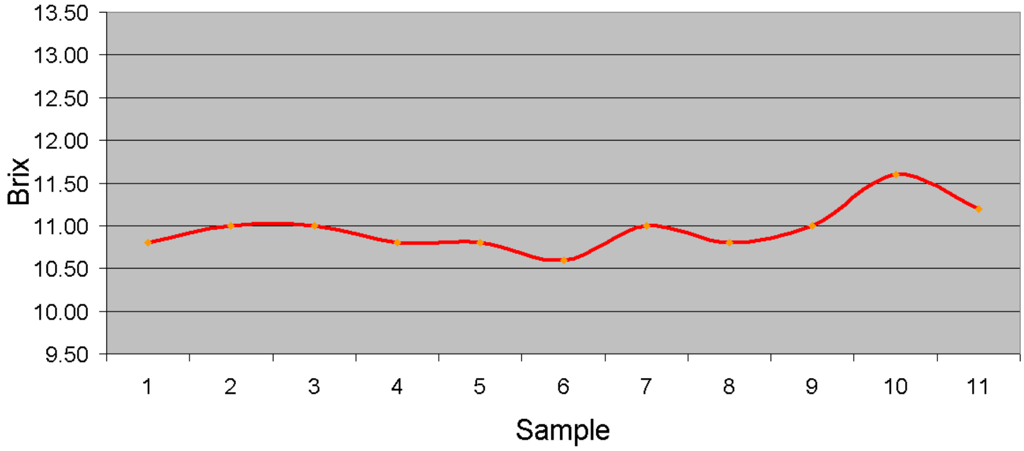
- ACE (based on vitamin A, C and D)
- Tropical
- Apple
- Orange (with cells)



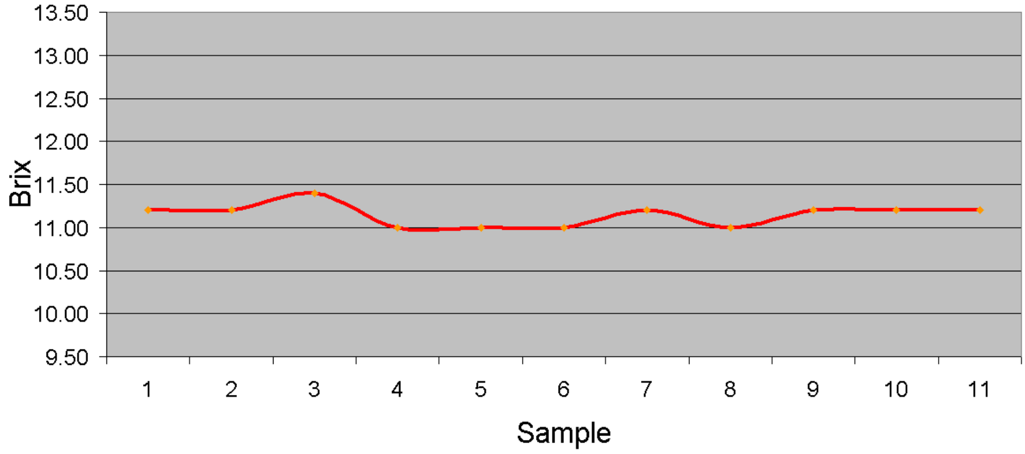
Tropical concentrate dispense test
Brix deviation – 1.42



Apple concentrate dispense test
Brix deviation – 1.00



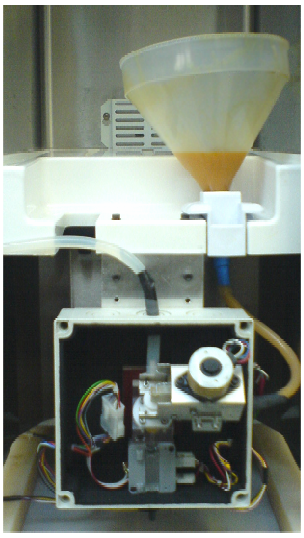
Orange (with cells) concentrate dispense test
Brix deviation – 0.40



As can be seen from the dispense test results the performance of the dispensing unit did improved dramatically, especially with orange concentrate containing cells. However it was felt that the new photodiode was probably not the most suitable unit. This had been chosen, from BCN current product range, to assess the calibration circuit and to be used as a platform for the development of a production unit. Due to the EC funding guidelines the manufacture of production units must be concluded outside craft projects.

Following on from the Safevend craft project and based on the research data, BCN are now developing, along with input form Autonumis and SDF, a specific production photodiode. This photodiode will be optimised for use in the Safevend machine and will be a new production unit.

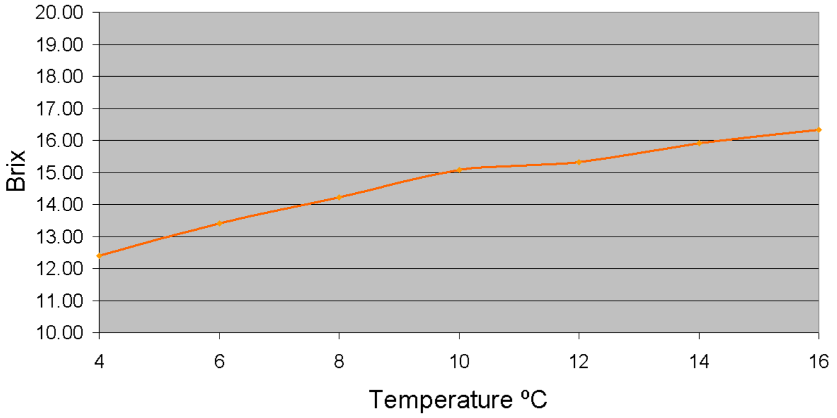
Temperature dispense tests:



In order to maintain consistent testing regime all data has been gathered with the concentrate held at 14ºC. The viscosity of the concentrate is extremely dependent on temperature; as we were using a venturi principle to draw through the concentrate any variations in viscosity would alter the amount of concentrate drawn through the system, which would be reflected in the final dispensed drink.

In an attempt to clarify the possible lowest temperature that the concentrate could be held at, whilst effectively dispensing a drink, a series of tests were performed using the rig opposite. At temperatures ranging from 4ºC to 16ºC, at increments of 4ºC, a measured amount of orange concentrate was dispensed. The water flow and pressure was maintained at 1 litre per minute and 1.5 bar.

The brix value for orange, reconstituted from concentrate, is 11.20. The graph below shows that even down to 4ºC the venturi can dispense to 12.30 brix. However given that the system has to compensate for a small amount of clear water, which is delivered both before and after each dispense, the minimum dispense temperature would be around 10ºC. This would also allow for deviations in the consistency of the concentrate.

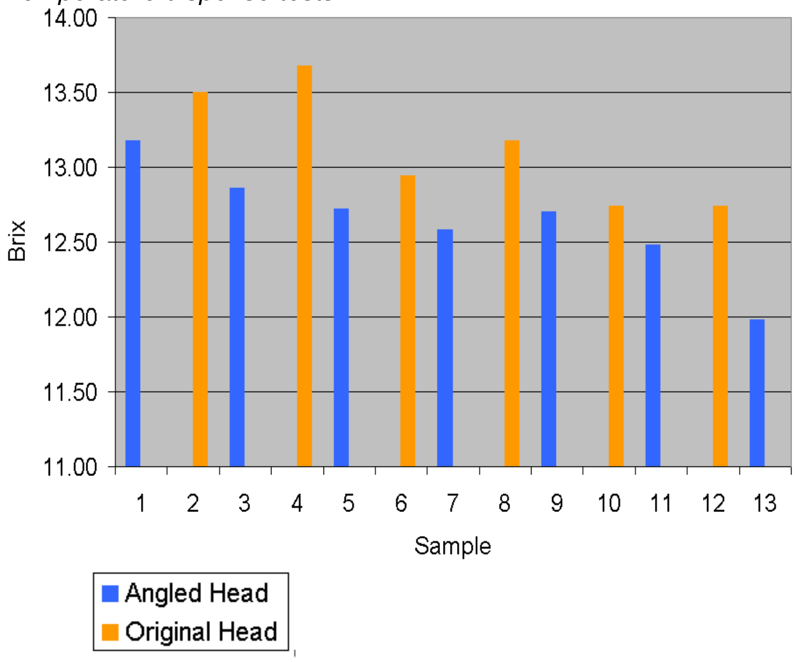


On evaluation of the temperature dispense tests it became clear that these were not truly representative of the final dispense system. All previous tests have used the standard aseptically sealed PET (polyethylene terephthalate) film bags, shown within a cage opposite. These bags a sealed and do not allow air to pass into the bag to replace the concentrate being removed. Therefore the PET bag is an additional factor that will affect the performance of the venturi.

To assess the impact of the PET bag upon the efficiency of the venturi a series of tests were performed, this time the concentrate was held ant 14ºC and dispensed from a PET bag that normally holds 10litres. The bag had been drained so that only 2.5 litres remained, to reduce the possible impact of the 'head' generated by a large volume of concentrate. So for a temperature of 14ºC the tests would place the greatest possible strain on the venturi.

These tests were performed on two variations of the mixing head, the most recent angled head and its predecessor, a standard venturi shown below. Measured samples were taken with each head, alternately, set to dispense a maximum brix, until the bag was empty. The graph below shows that the level of concentrate dispensed is reduced as the bag empties. This effect is more noticeable on the angled head as it is not an optimum venturi and, as shown during testing in task 5.2, actually pulls a reduced head compared with the original venturi. This data shows that for both heads the minimum concentrate temperature should be 14ºC, if a lower temperature is required then the incoming water flow must be increased, this will improve the performance of the venturi and allow it to pull a greater vacuum.

Temperature dispense tests



Angled head

Original head

Mix head cleaning:

Through testing in work package 4, hygiene assurance, it became evident that the venturi mixing head suffered form cleaning issues and 'dead spots'. The head was redesigned in task 5.1, Hardware Integration and Build, the new design featured a 45º reservoir to aid dispensing and cleaning.

To evaluate the performance of the mixing head trials were performed using the most viscous of concentrates, orange with cells. The cells are particularly difficult to remove and could cause problems in clogging the narrow apertures within the venturi and may become lodges under the needle valve causing concentrate to contaminate the clean water stream.

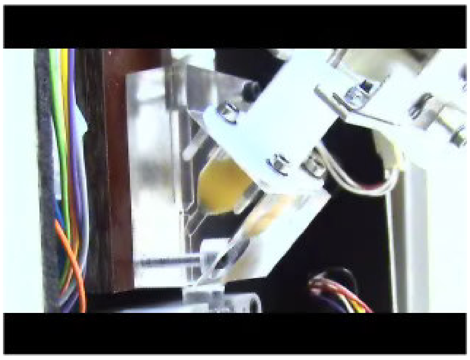
Angled mix head

Tests were performed under both dispense and cleaning conditions to evaluate performance. Below are two still images, taken form video footage which can be found on the project website, which illustrates the performance.

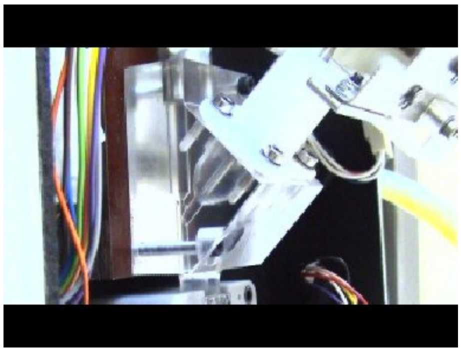
Whilst dispensing, cells that were trapped under the needle valves were pressed into the valve seat and did not cause leakage. During the next dispense the cells were drawn through the system.

During cleaning water was flushed through the reservoir, at the same time as water flowed through the venturi in the conventional way. Both water streams were restricted to 1 litre per second and 1.5 bar, to ensure that the tests remained realistic. The concentrate reservoir was evacuated within six seconds and was totally clear of concentrate and cells.

Stills taken from video footage – accessible through the project website



Mix head after dispense

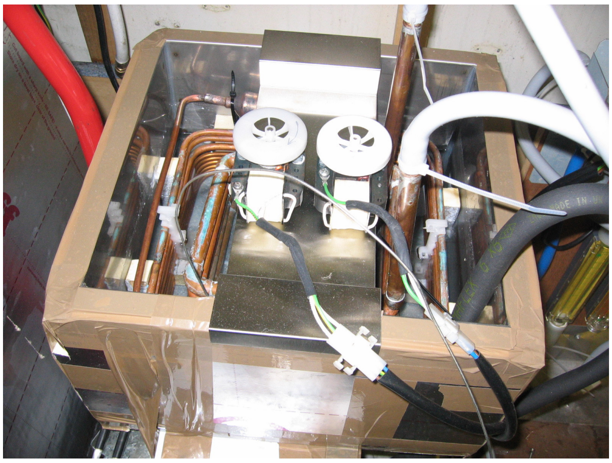


Mix head after cleaning

Water bath tests:

Incorporated into the cooling system is the water bath, this provides supplementary heat energy for the fruit concentrate. Given that the ratio of water to concentrate is 5+1 this can dramatically reduce the temperature of the final drink. This is especially useful when dispensing a drink to 5ºC, as earlier tests have proved that the minimum temperature for concentrate is 14ºC, given a flow rate of 1 litre per minute and pressure of 1.5 bar.

Water bath



Water bath test data

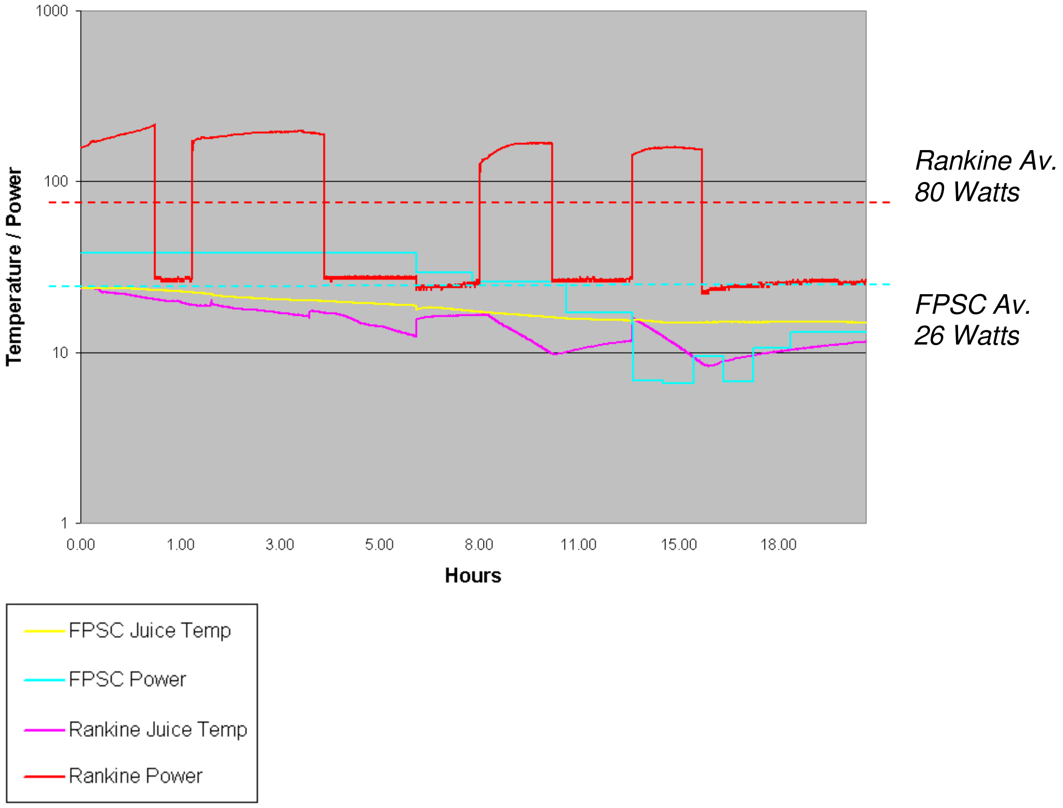
	KM CHILLER	SAFEVEND PROTOTYPE	BUNN 2 FLAVOUR	SAFEVEND SPEC.
ICE BANK WEIGHT	2,0Kgs	6,2Kgs	4,5Kgs	??
DISPENSE RATE	0,36 Ltrs/Min For 1 Hour @ < 7 ºC	1,5 Ltrs/Min For 50 Mins @ < 5 ºC	0,6 Ltrs/Min For 50 Mins @ < 5 ºC	1,0 Ltrs/Min For 1 Hour @ < 7 ºC
ENERGY ABSORBED BY	0,376 KW HOURS	1,359 KW HOURS	0,662 KW HOURS	

Cooling system tests:

Through development, integration and assessment of the 40W FPSC technology the consortium felt that, despite demonstrated efficiency, it did struggle to bring product (20 litres of concentrate) from an ambient of around 25ºC to 15ºC.

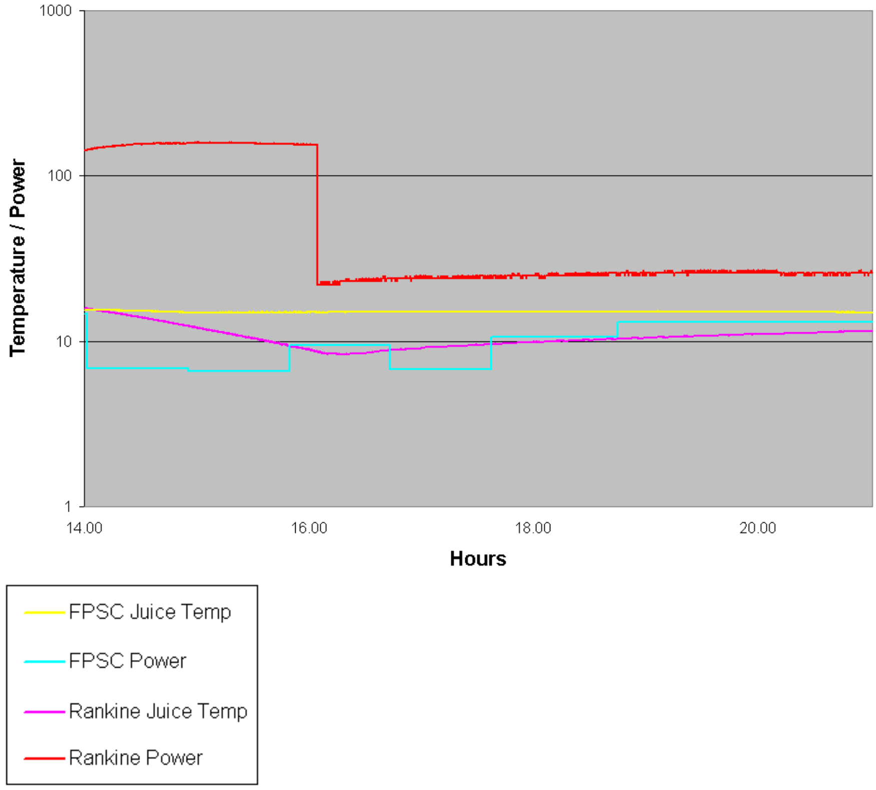
The graph below shows the initial pull down test for the FPSC unit in comparison with a conventional Rankine compressor. The Rankine compressor took 4hrs 54mins to pull the product down to 15ºC, compared to 13hrs and 11mins for the FPSC unit. Although the FPSC unit did take far longer to pull the product down to temperature it was operating at its maximum efficiency and was only consuming 25watts as opposed to the Rankine compressor that consumed 80 watts.

FPSC versus Rankine – Juice pull down to 15ºC from 25ºC (Ambient 25ºC)



The real benefit of the FPSC unit can be seen when the product is at temperature and the focus is on maintaining temperature, the following graph, illustrates the power consumption required to maintain the juice at 15ºC. This diagram shows the considerable improvement in efficiency of the FPSC unit over the Rankine compressor. The FPSC unit, when settled, uses a constant 13 watts. Compared to the Rankine unit, which is constantly cycling on and off, using an average of 44 watts. This resulted in a power saving of 70%

FPSC versus Rankine – Maintaining Juice at 15ºC (Ambient 25ºC)



In the pull down test the FPSC did suffer because of its limited capacity, as this is an emerging technology a full range of devices are not yet available. Given that the FPSC unit was only a 40 watt unit compared to the Rankine compressor which was 300 watt, the results of the pull down test were reasonable. The real benefit of the FPSC unit can be seen when maintaining the juice at a specific temperature, the improved performance and modulatory nature of the FPSC unit meant that it consumed considerably less power that the Rankine unit. The FPSC unit also maintained the cabinet and juice and a more accurate temperature, unlike the Rankine unit, which has a broad temperature range and cycles the compressor on and off.

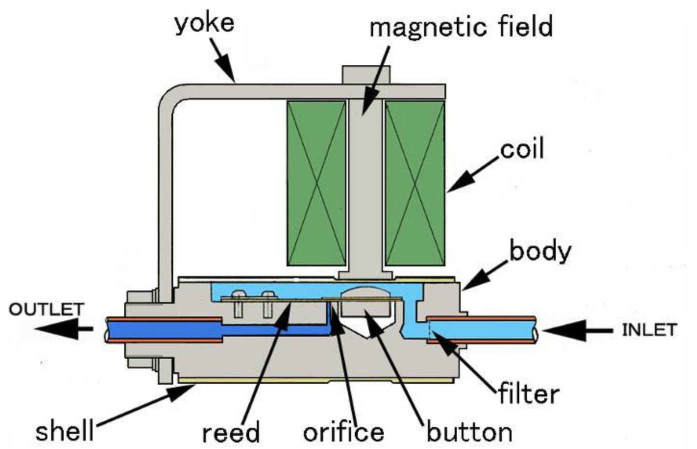
A 300 watt FPSC unit is currently under development and would be an ideal match for this application, having the capacity to pull down the product as quickly as a conventional compressor, whilst still having the efficiency of maintaining the temperature larger capacity FPSC will be available shortly.

Summary of FPSC benefits:

- Environmentally friendly
- High efficiency
- High reliability
- Continuously modulatable
- Compact components
- Ultra low temperature cooling
- Quiet operation
- Highly reliable structure and components

Given that presently the FPSC units suffered during the pull down test Global Cooling suggested an alternative solution, which would vastly improve the performance of the refrigeration system. The proposed technology, the Electronic Expansion Valve (EEV) would be a retro fir component added to a conventional Rankine compressor system.

The EEV operates on the pulsed-flow principle. An electrically actuated reed valve is pulsed open at two-second intervals. Flow rate is proportional to the fraction of the pulse interval during which the reed valve is open. This fraction is controlled by superheat as measured by thermistors. Stabilization of superheat is achieved with an inexpensive, passive, “superheat stabilizer”, which performs the function of an expensive PID control and is, in its simplest form, a section of tubing typically 20 mm Diameter x 200 mm length, in the suction line preceding the thermistor that measures vapour temperature.



The Electronic Expansion Valve cross-section view

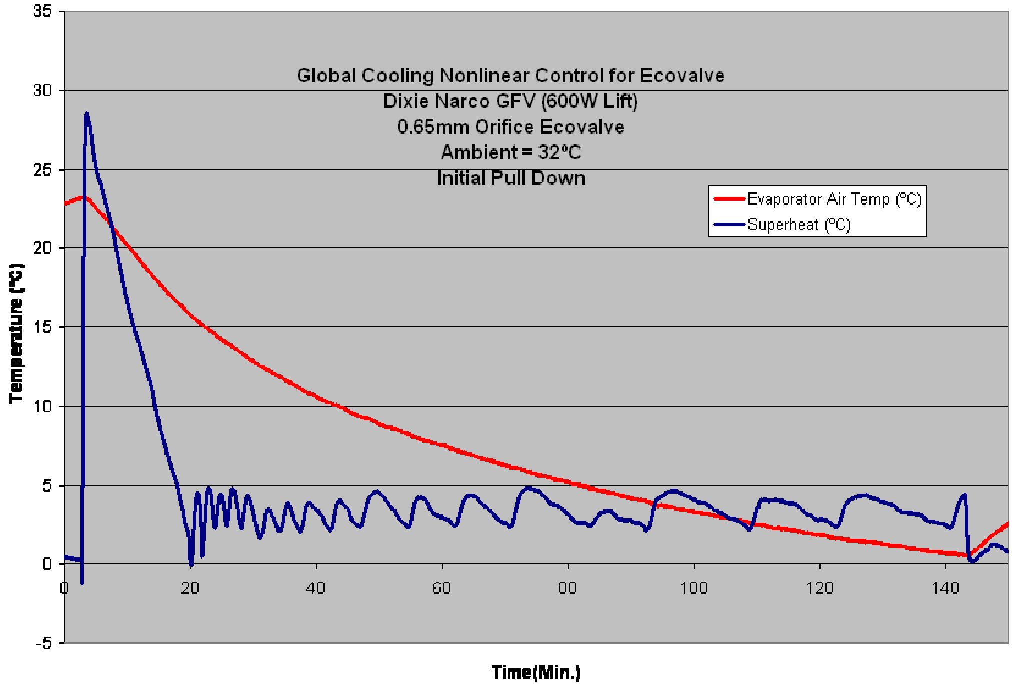
Performance gains:

- Control of refrigerant flow down to low rates of 15 W or less of refrigeration. A range of presently available orifice diameters enables flow control to 1200 W refrigeration, and higher flow rates are possible with a larger valve body.
- Maintains stable superheat of 3ºC, even at low flow rates.
- Small and easy to install by brazing into the liquid line at the evaporator inlet. The control unit is small, easily installed, and uses only 0.5W average power.
- Works with all common refrigerants, e.g., R134a, R22, R407C, isobutane, etc.
- Very low leakage reduces stop-start loss and minimum controllable flow.
- Digital control with an inexpensive microprocessor

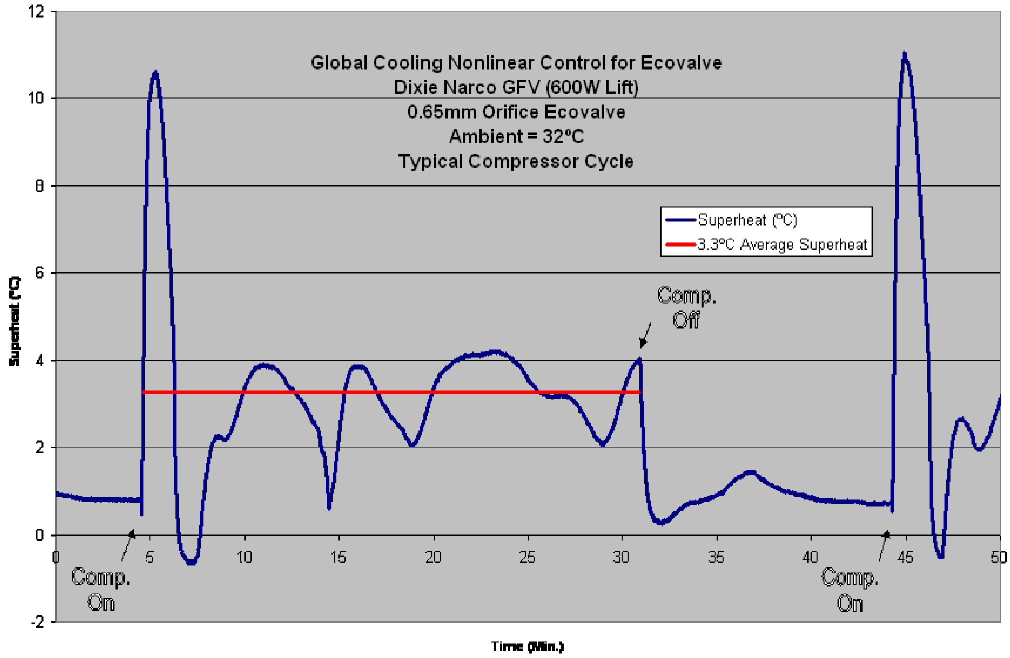
The real benefit of the EEV comes when the refrigeration machine is operating outside of its normal temperature. All refrigeration systems are designed to perform optimally at a specific temperature, the Safevend system is design for an ambient of 17ºC, which obviously this varies significantly with seasonal changes. A comparison between the conventional capillary system and the EEV is fair. However the capillary, as with the Rankine compressors is optimised for a specific temperature, 19°C, whereas the EEV was better over a wider range.

The following graphs show the performance tests carried out by Global Cooling on the EEV in an ambient temperature of 32°C

EEV pull down test (Ambient 32ºC)



EEV typical compressor cycle (Ambient 32ºC)



Work Package 6 – innovation Related Activities

Task 6.1: - Protection of IPR (D19)
Task Leader: Partner 1 - AUTONUMIS

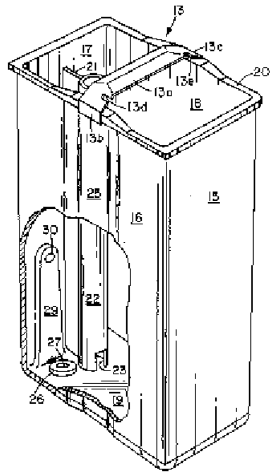
Objectives:
To ensure that all project results are formulated and compiled into a form that can be protected and all necessary patents are made.

Progress:
A patent agent has been identified and interviewed to ascertain their suitability to progress IPR protection. A meeting has taken place between the coordinator, Pera and the patent agent, 25/08/05, to evaluate the novel technologies and patentable items.

Sample Patent Information:
A selection of patents that include features similar to those being developed in the Safevend project have been identified, however, through a detailed review of the patents no conflicting articles have been found. Brief summaries, taken from three relevant patents, can be found below:

Juice Level Indicator System

- Lancer Corp (US).
- Used with Minute Maid dispensing systems.
- Minute Maid is a division of Coca-Cola foods.
- Refillable concentrate tank with sensors connected.
- Current passes between detectors in the sidewall and bottom wall when both are covered by liquid concentrate.
- Indicates when concentrate needs to be added to the tank.

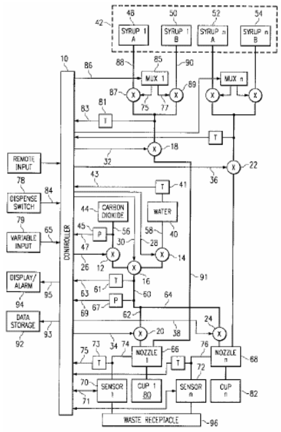


'Ratio Recognition Label'

- Lancer Corp (US).
- Used with Minute Maid dispensing systems.
- Minute Maid is a division of Coca-Cola foods.
- Pressure-sensitive bar code type label.
- Identifies different concentrations.
- Metallized PE label.
- Code read by IR scanner.

Brix measurement/control

- Texas Instruments Inc (Us)
- Automatically sensing and controlling quality for soft drinks
- Measuring syrups
- Fixed optic sensor, measuring one or more properties of the sample, such as, for example
  - o Refractive index
  - o Temperature
  - o Pressure



Safevend patent information:

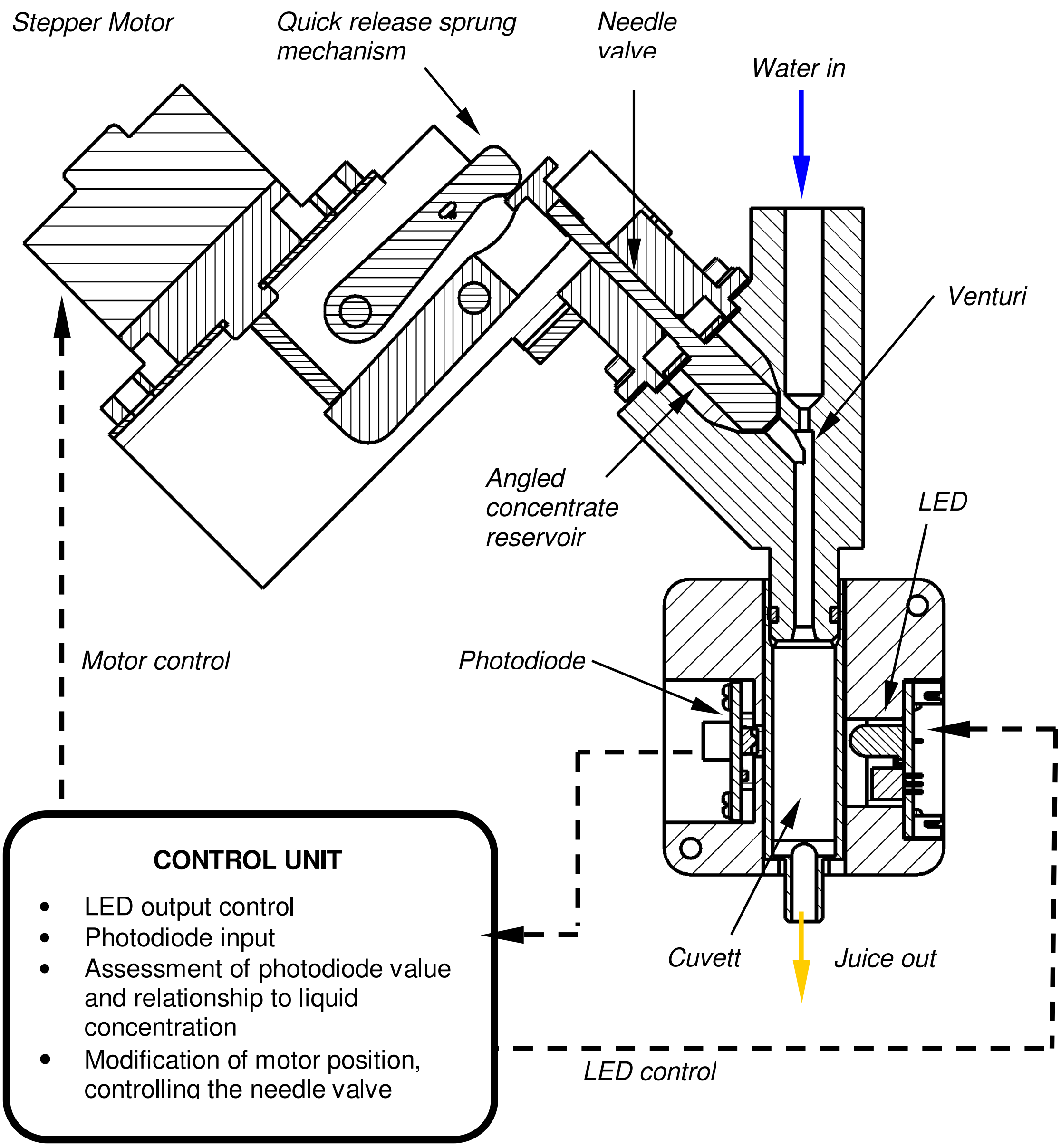
Following the selection and outline meeting with the patent agent the Safevend system, has been developed further and now reached a point whereby the main patentable innovations have been identified.

An outline of the possible patentable aspect of the system, the mixing head, measurement chamber and motor control, has been drafted as a starting point for the patent agent. Who has now been instructed to draft a legal document called a 'specification', the contents of which will determine whether a patent can be granted.

Outline dispense system description:

1. User request a drink
2. Information read from the RFID tag including:
   a. Customer code – to certify that this beverage should be dispensed form this machine
   b. Shelf life and use by date
   c. Amount of drink dispensed to date, ensuring that adequate liquid remains.
   d. LED output value – specific to beverages with differing degrees of translucency
   e. Set point – Specifies the output that should be received from the photodiode, given the correct mix ratio of water and concentrate.
3. The LED is turned on and a calibration routine started, measuring the output from the photodiode, relative to the clear water. This ensures that any drift in the output from the LED and response form the photodiode is compensated for and does not affect the light transmission readings through the drink.
4. Mains water is released into the system, entering the venturi and creates a vacuum at the intersection with the concentration reservoir.
5. The concentrate reservoir is angled, relative to the mains water inlet, to remove any 'dead spaces' where concentrate may sit and not be pulled into the drinks line.
6. The stepper motor opens the needle valve and moves to the last dispense position that gave the correct set point from the photodiode, thus improving the response time.

7. The absorption/transmission levels of the LED, through the mixed beverage, are measured by the photodiode. The needle valve position is modified accordingly.
8. For the first few seconds of dispense the concentration level is higher than the actual set point required. This is to compensate for the clear water that is dispensed at the beginning and end of each drink.
9. Once the compensation period has been completed the system settle down to dispense a drink to the actual set pint as specified on the RFID tag.
10. As the drink nears the end of the dispense the needle valve closes. The mains water continues to flow for a period after the needle valve has close to clear any concentrate form the internal surface of the cuvette and the exposed face of the needle valve.



Task 6.2 – Absorption of results by Proposers (D20)
Task Leader: Partner 1 - AUTONUMIS

Objectives:
To produce support material, which will enable the transfer of knowledge to the partners.

Progress:
Through the development of the Safevend prototype a full system design has been generated, this in turn has been manufactured to form a case study demonstrator. The demonstrators contain all of the principle innovations and link these innovations to form a complete working dispensing machine.

The dispensing machine and software has been demonstrated to the partners, who have been involved in all aspects of the research and development, and all encouraged to become familiar with full system operation. The prototype will reside with the co-ordinator and be made available to all of the partners. Each partner has been supplied with full documentation for all aspects of the device including algorithms, circuit board layout, 3D computer models of the enclosure, parts listings and configurations. In addition all technical reports and documentation is currently available, restricted to project partners only, through the Safevend project website.

Task 6.3 – Dissemination of Knowledge (D21)
Task Leader: Partner 6 - NORPE

Objectives:
To present, the Safevend system, major exhibitions/conferences and publications in the form of editorials, technical papers and trade press.

Progress:
Market stimulation and the publishing of innovations, generated by the Safevend project, has been minimised. In order that once launched the products impact is maximised and to maintain a market lead. To this end an outline production system specification has been created by Autonumis, see annex 2, which will facilitate the development of a production prototype.

In light of the patentable aspects of the Safevend system it has been agreed, by the consortium, that at this stage Safevend should not be publicly disclosed as this could be counted as prior publication of the inventions. Any type of disclosure (whether by word of mouth, demonstration, advertisement or article in a journal), by the consortium, could prevent a patent from being granted. It could also lead to a patent being patent revoked if one was obtained. It is essential that , at this time, Safevend is only disclosed under conditions of strict confidence

Once the patent application has been filed the production prototype will be presented at BRAU Beviale trade fair in Nürnberg, 15th-17th of November. BRAU Beviale is one of the most important European trade fairs for the production and marketing of beer and soft drinks, with 1,400 exhibitors and 38,000 trade visitors. The annual trade fair ensures a successful mixture of an extensive range of beverage raw materials, technologies, logistics and marketing.

Task 6.4 – Socio Economic Aspects (D22)
Task Leader: Partner 6 – NORPE

Objectives:
A report on the standards, ethical and regulatory aspects of the exploitation of results.

Progress:
To this end outline production system specification has been created by Autonumis, see annex 2, which outlines the European and International standards that the product should comply with. Additional reports related to European Hygienic Equipment Design Group EHEDG can be found on the project webpage.

EHEDG is an independent consortium formed in 1989 to develop guidelines and test methods for the safe and hygienic processing of food. The group includes representatives from research institutes, the food industry, equipment manufacturers and government organisations in Europe

Project Web Page – European Hygienic Equipment Design Group (EHEDG) documentation

- In-Place Cleanability Test Of Food Processing Equipment (EHEDG Doc 2)
- In-Line Pasteurisation Test Of Food Processing Equipment (EHEDG Doc 4)
- In-Line Steam Sterilisation Test Of Food Processing Equip. (EHEDG Doc 5)

Task 6.5 – Promotion of Exploitation (D23)
Task Leader: Partner 6 – NORPE

Objectives:
100 companies contacted directly to promote the results. 25 companies stimulated to apply or use the results in their product strategy. 10 companies engaged in detailed knowledge or technology transfer, 3 years post project completion. 5 European companies facilitated to adopt the results in the generation of new products or services, 3 years post project completion.

Progress:
Initial market research/stimulation has taken place, contacting the companies below to asses their willingness to adopt new technology. However the specific details of the Safevend project have not been divulged to any person outside the Safevend consortium. More detailed discussions, with third parties, will take place on completion of patent applications

Machine Operators:

- Compass
- Sodexo
- Balmoral
- Krogab UK
- Krogab Finland
- Krogab Sweden
- Krogab Norway
- Krogab Denmark
- Arla
- Vitality
- Eckes Grannini - Germany
- Douwe Egbert - T/A Merrild, Denmark
- Douwe Egbert - T/A Merrild, Sweden
- Douwe Egbert - T/A Maison du Coffee Systems
- Douwe Egbert - T/A Marcilla Coffee Systems, Spain
- Douwe Egbert - Head Office, Utrecht

Brand Owners:

- Britvic
- Tropicana - PepsiCo International
- Del Monte - Cirio Delmonte
- Outspan - Capespan International
- Coca Cola/Minute Maid
- Arla (Jo Bolaget)
- Rynkeby – (owned by Arla)
- Oranka - Holland
- Tine - Norway
- OC22 - France

It is also planned to present a production prototype at the BRAU Beviale trade fair in Nürnberg, 15th-17th of November, which typically attracts 38,000 trade visitors.

Work Package 7 - Consortium Management

Task 7.1: - Coordination of knowledge and IRA (D24)
Task Leader: Partner 1 - AUTONUMIS

Objectives:
To ensure that that the knowledge management processes are implemented in a coherent manner.

Progress:
A preliminary technology implementation plan has been developed and the production specification unit specification drafted by Autonumis, see annex 2.

Task 7.2: - Co-ordination of the technical activities (D25)
Task Leader: Partner 1 - AUTONUMIS

Objectives:
Ensure that all aspects of the EC requirements for communication and reporting are met. The Co-ordinator will be the sole point of contact between the EC and the partners, and is responsible for:

Progress:
Delivery of the six-month progress reports, mid term review report and this report, which is the final project report. Cost statement submission. Organise kick-off, mid tem and final meetings.

Task 7.3: - Co-ordination of legal aspects (D26)
Task Leader: Partner 1 - AUTONUMIS

Objectives:
The objectives are the co-ordination of legal, contractual, financial and administrative aspects of the project.

Progress:
Provision of bank guarantees and audit certificates at the end of the project

Task 7.4: - Coordination of other issues (D27)
Task Leader: Partner 1 - AUTONUMIS

Objectives:
The co-ordination of gender equality, ethical and science and society aspects of the project

Progress:
The Societal and policy objectives of this project are to improve the health and quality of life of the adult and children users of vending machines. The proposed technology will reduce the risk of food poisoning and protect our environment by reducing the amount of power consumed.

The ethical relevance of the project is not applicable, as the research does not involve any testing on animals, humans, plants or any other living species.

The project is non-gender specific, the end product of fruit juice is marketed at society as a whole and not specifically at any one section. The fruit juice dispensing/vending equipment will be installed in venues as diverse as motorway service stations; exclusive and budget hotels; workplace canteens and restaurants; and schools and colleges. This installation policy will target an extremely diverse demographic.

Social and economic issues are taken into consideration in the research activities of this project and partners are informed about and are aware of the social aspects with regard to scientific and technological progress. The benefits of research in support of socio-economic policy challenges would be enhanced by the integration of socio-economic research.

A questionnaire will be distributed to each project partner to facilitate the monitoring of the integration of the socio-economic dimensions in FP6 and to finally support the assessment of the research that will guide the future policy formulations and decisions.

PROJECT NO: FP6-508402

SAFEVEND

New generation automated fruit juice vending machine
To reduce food poisoning of the children and the working population

Co-operative Research (Craft)

Horizontal Research Activities Involving SMEs

APPENDIX 2 – Product Specification

Final Activity Report
Date of issue of this report: May 2006

Start Date: 1st February 2004 Duration: 27 Months

Lead Contractor: Autonumis Ltd

Version 0.1