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ANNEX 2: TEMPLATE FOR PROPOSAL UNDER DERRI

User-Project Proposal:

Use-Project Acronym	INVERTER
User-Project Title	Development of new PVC separators and non woven gauntlets for home UPS batteries: the Inverters
Main-scientific field	Electricity storage
Specific-Discipline	Security of the grid

Lead User of the Proposing Team:

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Activity type and legal status* of Organization	Other : SME but wholly owned subsidiary of THE MOORE COMPANY, headquartered in Westerly, R.I., USA.
Position in Organization	R&D Manager

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

Additional Users in the Proposing Team:

Name	
Phone	
E-mail	
Nationality	
Organization name, web site and address	
Activity type and legal status* of Organization	
Position in Organization	

* Higher Education Institution (1) – Public research organization (2) – Private not-for-profit research organization (3) – Small or Medium size private enterprise (4) – Large private enterprise (5) – other (specify)

(Repeat for all Users)

Date of submission	05/2010
Re-submission	YES_____ NO_ X _____
Proposed Host TA Facility	TA3 – CEA- Le Bourget du lac - FRANCE
Starting date (proposed)	01/09/2010

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Summary of proposed research (about ½ page)

The project proposal is part of a R&D project which consists in developing both new separators and new gauntlets for industrial lead acid batteries, especially battery for special Uninterrupted Power Supply (UPS) system called Inverter which is a cycling UPS. The aim is to develop products with better properties than the products already on the market ie: have a lower electrical resistance, improve charge acceptance and speed of charge, improve temperature resistance, improve partial state of charge and battery life time. Another aspect of the project is to develop such products at a lower price than products sold, at the moment, by Amer-Sil and its competitors because the targeted customers are mainly located in emerging countries where power outages are long and frequent.

For separators, we have developed a PVC-silica based separator with a thinner backweb of 0.30 mm (thickness without the height of ribs) than our standard range (0.60 mm). This development which allows raw material cost reduction was made thanks to change in the formulation and in the production process. Yet, mechanical properties (resistance to pressure, resistance to oxidation, elongation…) and structural characteristics (pore size, volume porosity…) have changed and must be validated in battery tests.

For gauntlets, we are developing a non woven gauntlet for positive plates based on a non-woven technology which is not used for battery market but which is cheaper than non woven fabrics used at the moment. Extensive work on a new impregnation resin on this fabric and on the forming process will also lead to better performance and cost reduction. As for separators, this new gauntlets has to be tested in battery.

Amer-Sil is well equipped to test 2V cells for main UPS batteries but does not have the equipment for testing 12V monobloc battery. Unfortunately, one kind of UPS battery called “Inverter”, which has to be evaluated in this project is a12V monobloc battery. Inverters are home UPS: it is a two-in-one product (inverter + UPS battery) which is a power back-up system at home for household appliances during power cut.

In emerging countries such as India, Inverters have become a mandatory office and industrial tool considering the power supply position of the country. Thus, Inverters have become a daily use item at home and in business as well and help in supporting the security of grids.

The expected outcome of this study is to provide better components for inverter batteries which will allow inverters suppliers to extend their warranty (for example from 36 to 48 months for tubular batteries) and deliver inverters at lower price, that means to more people. Ideally, we would also like to define precise specification for PVC separators and non woven gauntlets in inverter battery applications. We also hope that this project and it communication in emerging countries will promote R&D projects on lead-acid batteries and components in these countries and step by step, help them to start working in the safe and efficient technology of gelled electrolyte batteries.

State-of-the-Art (about 1 ½ page)

As far as we know, there is no publications or scientific work on battery components dedicated to Inverters. Indeed, manufacturers are mainly located in Asia and they use cheap local products without, up to now, really show a desire and a need to understand the technology behind the products. Besides, western companies are not spending a lot of time and money to respectively enter the market and develop better components at lower price. Thanks to contact with different manufacturers, we know that for the moment, flat plates batteries represent 60% of the market but because of the strong need to improve performance, tubular plates technology is increasing.

Development of non woven gauntlets

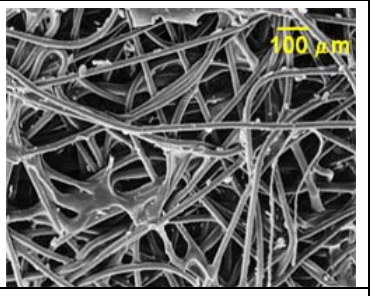
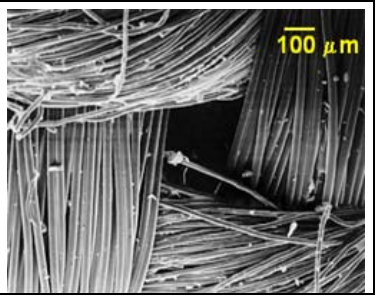
For tubular batteries, gauntlets must be used and Inverters manufacturers used woven gauntlets because it is a well known technology in Asia with a lot of suppliers. Yet, leader manufacturers of inverters ask now for help to develop better batteries and show a strong interest to non woven technology which is well known to improve capacity and cycling life [1].

Indeed, their higher efficiency is mainly due to the fabric physical properties. Table 1 gives some reference numbers on porosity and acid retention. As mentioned, the overall pore volume of non-woven mats is around 70%, which is much higher than the 40% reached by the woven fabrics. Also the pore size distribution is different, with lower pore size for the non-woven fabric (mean pore size around 30 µm compared to 100 µm for the woven type), mainly due to the random filament deposition on the conveyor belt during the spunbond mat manufacturing process. The different pore structure, and especially higher pore volume associated with lower pore size for non-woven fabrics leads to a better fluid management, and especially a higher ability to absorb and retain the electrolyte inside the pores, thanks to higher capillary forces : it has been measured that an average 0.12 $g.cm^{-2}$ acid is absorbed inside the non-woven fabric pore structure, while only 0.05 $g.cm^{-2}$ stays in the woven material. This phenomenon leads to improved ionic exchanges through the fabric wall, and consequently to reduced electrical resistance of fabric. As a result, the electrical resistance of the non-woven gauntlet itself is also very much reduced, leading to lower cell internal resistance and higher battery capacity.

Reduction of the electrical resistance is not the only consequence of the different microscopic structure of both types of fabrics. The lower pore size of the non-woven fabrics has a beneficial impact also later in life, thanks to the greater ability of the mat to retain small crystals. It is actually recognized that the positive active material suffers degradation when repeated charge/discharge cycles occur, because the alternating dissolution and precipitation processes convert the agglomerated initial paste structure into an accumulation of fine crystals. This process known as “shedding” is responsible for the loss of active mass through the gauntlets walls. On weighing the shed active mass accumulated at the bottom of cells after cycling, it has been found that the deposit is 1/3 reduced with non-woven gauntlets due to the finer pore structure of the fabric. The importance of keeping fine crystals inside the tubes had already been outlined elsewhere, as they also act as binders to the positive active material, hence increasing performance and cycle life [2-3].

Figure 1 clearly shows the benefit of a better active mass retention inside the non-woven gauntlets, as 1100 accelerated cycles have been performed with non-woven gauntlets compared to only 700 with the woven gauntlets on flooded traction cells.

Tableau 1 : woven and non woven characteristics

	Pore size (µm)	Volume porosity	Scanning Electron Microscopy
Non woven	Max = 40 Mean = 29 Min = 17	70 %	
Woven	Max = 123 Mean = 89 Min = 17	40 %	

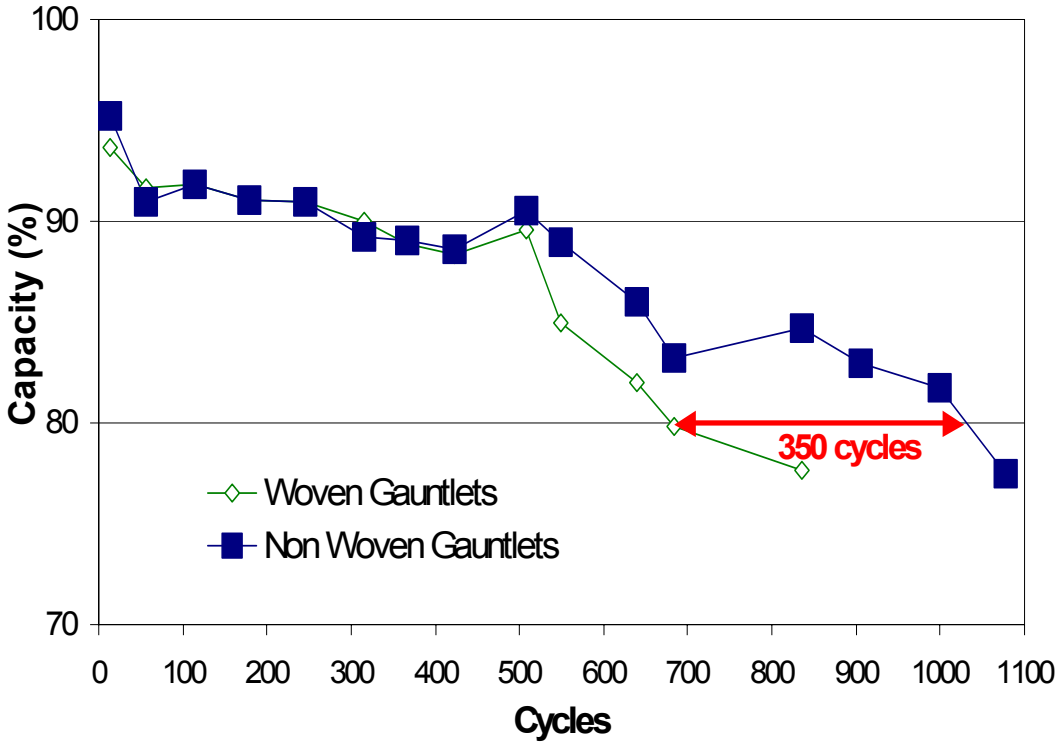
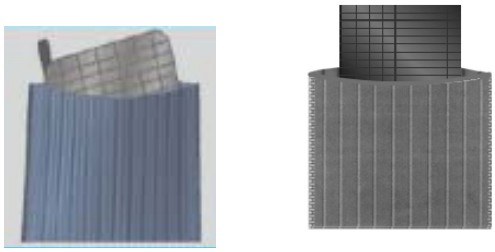


Figure 1 : Accelerated Life Cycle test results of Traction Cells using woven and non-woven gauntlets made of polyester spunbond point-bonded fabric.

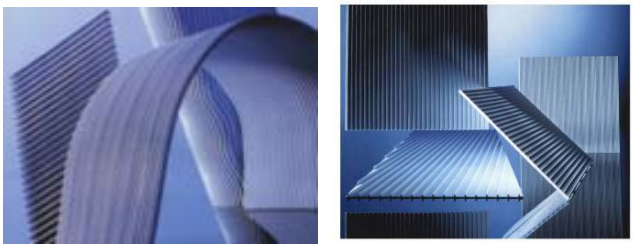
In summary, non woven advantages are: higher volume porosity and lower pores size which give better active mass retention and lower electrical resistance but the disadvantage is a lower tensile strength and higher elongation which means lower elasticity and lower burst strength.
That is why woven and standard spunbond continuous polyester filaments non woven gauntlets for industrial batteries (traction, stationary) are not suitable for the Inverter market because inverter batteries are not really stationary batteries, they cycle! Power shortage can last up to 8 hours in rural cities that mean the battery suffers from high level of discharge every day. The scientific lock is consequently to give to non woven gauntlet enough elasticity to support cycles.
Amer-Sil has already develop in 2005 new gauntlets made of flat calendered bicomponent fabrics [4] which combined electrical advantages of standard non-woven fabrics, with quite optimized mechanical and elastic properties but this was a first step and we have now to develop another new generation of non woven gauntlets with higher performance, lower price and dedicated to special stationary batteries which cycle which are used when the grid is weak.

Development of thin PVC separator

For both flat and tubular batteries, PE envelopes are used because manufacturers copied SLI (Starting – Lighting – Ignition) batteries in automotive without understanding that the function of the inverters battery is not the same function at all than a car battery!



PE envelope from competition



Amer-Sil PVC leaf separator

Figure 2: PE envelope & PVC leaf separator

Leaf separator, especially the PVC based separator from Amer-Sil offer a lot of advantages compared to envelope. PVC leaf separator has much lower electrical resistance and acid displacement than PE envelope; that means higher capacity. Degassing and acid circulation is better with leaf separator; consequently, charging time can be improve and the overall impact on battery life and performance is positive. Moreover leaf separator provide a cost reduction up to 30% compared to envelope.

It is nowadays a common knowledge that separators play an essential role in the performance of Lead Acid batteries. This component, considered as the third electrode, has to be much more than an obstacle to dendrite growth between the opposite plates. The separator must not participate in increasing too much the internal resistance of the system. It has also to have a maximised pore volume in order to insert the less amount of insulating material as possible in between the plates

The results of a previous study performed on 130 Ah gel cells insulated with different types of separators with various pore volumes, have confirmed that high pore volume material can increase the performance of the battery [5-13]. The results are summarized in Figure 3 : cells assembled with 50% pore volume separators reached only 75 cycles, while cells assembled with 70% and 80% pore volume separators achieved 150 and 500 cycles respectively.

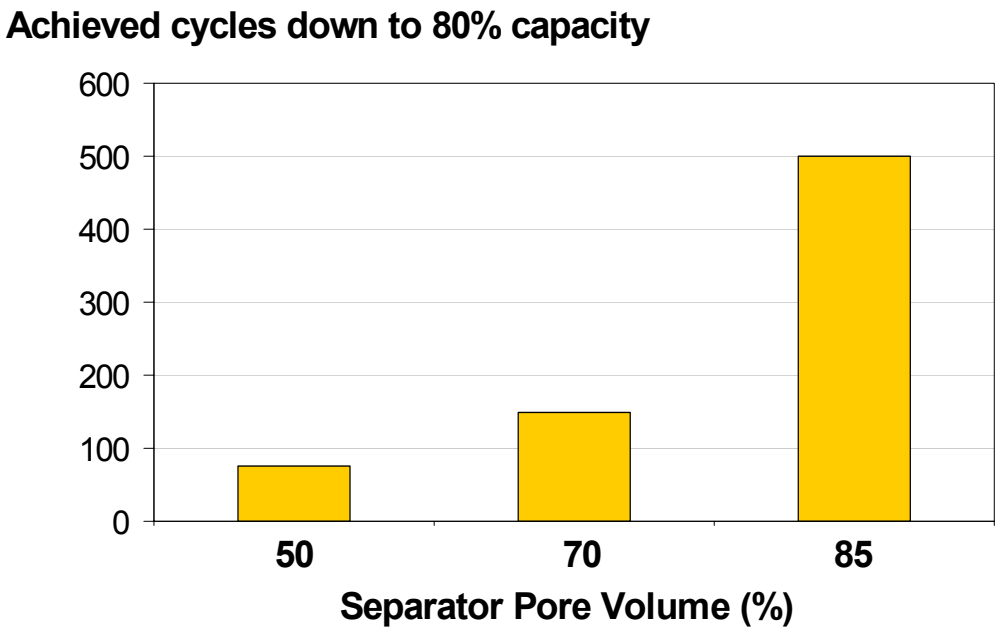


Figure 3 : Impact of the separators' pore volume on the electrical performance of 130 Ah gel cells. The accelerated life cycle test has been performed at C5, 47°C and 80% DoD.

Typical values	Amer-Sil ribbed	Amersorb ribbed	Amer-Sil corrugated	Amersorb corrugated	PE	Rubber	Phenolic resin	PE/rubber	AGM
Thickness (mm)	2.0	2.0	2.0	2.10	2.0	2.0	2.0	1.85	2.0 @ 20 kPa
Backweb (mm)	0.50	0.57	0.57	0.42	0.50	0.57	0.55	0.50	2.0
Total porosity (cm^3/g)	1.20	-	1.58	-	0.90	0.85	1.20	0.73	-
Pore volume (%)	68	76.9	73.9	82.4	55	53	70	45	92 - 95
Pore size (µm)									
Min	0.05	0.05	0.05	0.05					3.0
Mean					0.10	0.17	0.50	0.09	10.0
max	1	1- 5	1- 3	1 - 7					30.0
Elec. Resistance ($m\Omega.cm^2$)	130	89	80	35	200	300	110	400	80
Displacement of acid (ml/m^2)	300	207	180	140	300	450	220	> 400	-
Oxidation weight loss (%)	3	3	3	3	5 – 20	15 – 30	29	23	3
Wettability (s)	2	1	2	1	5000	15	200	> 1200	1

Table 2 : Physical properties of main separators available on the market (typical values).

Concerning pore volume, the ideal is to increase the pore volume to a maximum value in order to reach the ideal "transparency" to ionic transfer. Table 2 shows that the PVC/silica separators have pore volume from 68% to 82.4% for the same 2.0 mm thickness, depending on the type and pattern : the standard Amersil ribbed separator has 68% pore volume, while the Amersorb ribbed reaches 76.9%. The corrugated patterns, obtained by deforming a flat sheet under hot calender rolls, can reach 73.9% pore volume for the Amersil (compared to 68% for the ribbed pattern), and

be as high as 82.4% for the Amersorb (compared to 73.9 for the ribbed pattern). These PVC/silica separators are the most porous separators nowadays available. For comparison, only the phenolic resin separator can compete with the former materials with 70% pore volume. All the other types have a much lower pore volume : only 45%, 53% and 55% for Polyethylene/rubber, Rubber and Polyethylene respectively.

Nevertheless, in the case on Inverters, Amersorb but also standard Amer-Sil separators are too expensive. That is why we have to develop another separator for even lower electrical resistance and reach better performance at a lower price.

References

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Detailed Description of proposed project : Objectives – Expected Outcome – Fundamental Scientific and Technical value and interest (2-3 pages)

The objective of this project is to develop separators and gauntlets for 12V monobloc lead-acid batteries dedicated to inverter batteries which will allow a significant increase in life time, improvement in charge acceptance and capacity. More precisely it consists today to propose newly developed products based on theoretical, empirical and practical considerations, to validate them and help us to define with the more accuracy as possible specifications of products for optimal performance.

The task to be done is consequently to test different combination of new products (non woven gauntlets & PVC separator) versus the products used at the moment (woven gauntlets & PE envelope) with a testing procedure which represents the reality of an inverter battery life.

We have planned to test the new developed AS10 non woven gauntlet and the new developed separator with reduced backweb in comparison with our standard range of separator and gauntlets and in comparison with woven gauntlet and PE envelope used at the moment. Luminous , one of the leader of Inverters systems in India has offer his help to build 9 kinds of inverters battery and provide us woven gauntlet and PE envelope.

The 9 kinds of battery are listed in the following:

A. Tubular plate

1. Standard 6.2 mm tubes diameter PE leaf with 0.45 mm backweb and woven gauntlet

2. Standard 8.0 mm tubes diameter PE leaf with 0.45 mm backweb and woven gauntlet

3. Improved T1 6.2 mm Non-woven standard type and new corrugated separator 0.3 mm backweb

4. Improved T2 6.2 mm New Non-woven type AS10 and ribbed DWN separator high-porosity

5. Improved T3 6.2 mm New Non-woven type AS10 and corrugated high-porosity separator

6. Improved T4 8.0 mm Non-woven type AS03 and new corrugated separator 0.3 mm backweb with glassmat against the negative

7. Improved T5 8.0 mm New Non-woven type AS10 and ribbed DWN separator high-porosity

B. Flat plate

8. Standard PE sleeve with 0.35 mm backweb

9. Improved F1 new corrugated separator 0.3 mm backweb with glassmat

Two batteries of each type will be tested with the following procedure which represents most closely the reality in the field.

1- Discharge at 0.1 C10for 8 hours or 10.5V of the battery
2- Charge:
Charge at 0.15 C10 with CC current till 14.5V
Charge at 14.5 V with CV for 5 hours – max charge current 0.15 C10
3- After 30 cycles:
Conduct 1st C10 discharge
Charge at the rate of 0.1C10 up to 14.5V and further charge at the rate of 0.05 C10 for 5 hours.
Conduct 2nd C10 discharge
Recharge the battery with the same regime as mentioned in earlier step in 3-
4- End of the test when 2nd C10capacity reaches below 80% of the rated capacity.

The discharge time of 8 hours represents the worst case condition in rural areas compared to two hours in cities. The all procedure and tests will be run at 30°C. A tear down is also needed. It will consist to evaluate the ageing of separators and gauntlets, especially their mechanical properties.

With this procedure, we will be, of course, able to conclude if the new range of products developed for inverters is better in life time, charge acceptance and capacity than the solution used at the moment by inverter manufacturers. But the fact of including our standard range of PVC separator and non woven gauntlets will also allow us to understand the key parameters in inverter performances and define special specifications for this application.
For gauntlets, we will understand and delimited mechanical properties (elasticity, force of compression, resistance to pressure, shrinkage ratio), physical properties (porosity, surface properties) and chemical properties (oxidation resistance; amount of chemical impurities allowed, resin content) needed to obtain maximal capacity, charge acceptance and life time.
For separators, it will allow us do define more precisely mechanical properties (elongation , tensile strength, resistance to pressure, shrinkage ratio), physical properties (mercury intrusion porosity, volume porosity, distribution of pores, wettability) and chemical properties (chemical impurities content limit, chlorine content limit, oxidation resistance, thermal stability) required for optimal capacity, charge acceptance and life time.

This work will perhaps lead to another one if results show that we can still improve products and that results obtained seem not to be optimum. And, as we will explain it in the folowing paragraph, we hope that it will encourage manufacturers to conduct R&D projects and propose new design, new components or even start evaluate gelled electrolyte in inverter batteries.

Originality and Innovation of proposed research – Broader Impact (1-2 pages)

As already mentioned, there has never been projects to develop separators and gauntlets dedicated to inverters batteries. Moreover, it is almost certain that non woven technology in gauntlets, as well as PVC separators which are the more porous on the market have never been evaluated in such batteries! The technical challenge is really to develop components dedicated to these special stationary batteries which cycle!

Besides, for gauntlets, the innovation is the use of a special non woven fabric which has never been used or tested in any batteries and consequently, innovation in resin type and resin impregnation and forming process to deal with this special fabric. The results of lab tests evaluation show reinforced mechanical properties for better processability and improved elasticity to better guaranty an active mass compression in critical cycling applications.
Woven fabric offers a high longevity thanks to its good oxidation resistance and constrain the active mass around the spine and have less tendency to expand. However, the electrical output of the batteries are not fully optimized and the capacities are reduced due to the higher electrical resistance of the woven gauntlets.
With the newly develop non woven gauntlet, we expect that the high quality of the continuous polyester filament used to produce the non-woven fabric as well as the level of new acrylic resin used to further protect the base material, will make the final gauntlet resistant enough to keep its integrity and properties during the whole battery life. We think that the mechanical properties (especially dilatation/retraction) have been improved to reach the level of most woven material, therefore ensuring a good active mass compression and the requested battery longevity. Tests

lab have shown that the electrical resistance has been maintained low and we hope it is low enough to take advantage of the non-woven fabric and gain a few percent of capacity.

For separators, the unique bimodal pore size distribution allows a fast ion exchange and a perfect protection against active mass transfer (no short circuit due to dendrite growth even in case of very high longevity). But the new developed separator with thinner backweb has also an instantaneous wettability and an open structure which reduces the resistance to the ion exchange to a minimum. We expect the capacity of the cell to be increased, but even more in case of high rate discharge. In addition, the corrugated patterns will further decrease the acid displacement i.e., allow a maximum amount of electrolyte in the cells. Finally, through the use of very pure raw materials, the separators do not contaminate the electrolyte with harmful metallic impurities and the raw materials used have a very high natural resistance to oxidation. Therefore, contrary to polyethylene-based products, the addition of a significant proportion of oil is not necessary to protect the polymer from degradation. All these parameters will normally increase the overall performance of the inverter.

In case of flat positive plate, the glass-mat of the separator has to be placed against it to better stabilize its structure ad maintain the active mass. However, if the positive plate is tubular, the active mass is well constraint inside the gauntlets, and therefore, the idea is to place the glassmat against the negative plate to reach an homogeneous negative plate expansion, i.e. oppose the same resistance and pressure on the whole negative plate surface, therefore avoiding its heterogeneous way of functioning. The results expected are an improved performance of the cell.

Nevertheless, it should be borne in mind that this project is not only to propose non woven gauntlets and PVC separators to give to Amer-Sil company more market shares. It is a first step to help manufacturers improve their products in performance and safety. Indeed, for the moment, whereas gel battery technology is the one which can offer great performance and security compared to liquid electrolyte, it is useless to help manufacturers in emerging countries to start with gel battery technology because they do not really understand yet batteries technology and are not ready for drastic changes. It means, for example, that they do not try to design optimal batteries and standardize them to reduce cost. If the new developed AS10 gauntlet improve significantly capacity, it could be possible, for instance, to remove one plate and have still the capacity required and thus reduce cost thanks to lead reduction. That is for this reason that we believe this project is a way to train people dealing with lead-acid batteries and step by step, help them to conduct R&D projects to improve performance and security of their batteries at lower cost.

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Proposed Host TA Infrastructure/Installation – Justification (about one page)

TA 3, INES in France would be the best collaborator because it has all the equipment needed, the right people with expertise and is not to far from Amer-Sil R&D lab located in Luxembourg. Indeed, INES has enough test benches and is the only structure with a chemistry laboratory for tear down analyses. Besides, we also already work with INES for Optimization of charge algorithm and battery design to improve cycling performance under partial state of charge operation; a project sponsored by the Advanced Lead-Acid Battery Consortium. Consequently, INES know already our products and our way of conducting R&D project and battery testing.

Amer-Sil will supply the 18 batteries free of charge and will support freight cost. The tests will be conducted by INES technical people and we planned around 2 visits of Amer-Sil people: one at the beginning of the project and one at the end.

Synergy with ongoing research (about ½ page)

As already mentioned, we do not know other research project dedicated to the INVERTER. Because this project is part of one bigger R&D project concerning the development of separators and gauntlets dedicated to UPS batteries, the objective is to evaluate the performance of separators and gauntlets developed in one hand for inverters and on the other hand for other kind of UPS batteries and then, cross the results and potentially adapt some products based on the overall results.

Dissemination – Exploitation of results (about ½ page)

We planned to present our work at the 14th ABC (Asian Battery Conference) which will be held in Chennai INDIA in September 2011. Other potential orals presentations or posters could be 4th IBRX India (international battery expo & recycling) in 2012 and CIBF (China industrial battery fair).

If results are sufficient and scientifically relevant, the redaction of an article, for example in Journal of Power sources could be done. We would also be interested to publish our results in specialized batteries magazine such as “Batteries and Energy Storage Technology Magazine” which is the world's leading publication on the global battery industry and the emerging field of electrical energy storage or in “The Battery Man magazine” which is a magazine edited by

the trade association of lead-acid battery manufacturers and suppliers.

We also planned to do a technical conference on this subject during the official inauguration of our new plant in China.

Time schedule (about ½ page)

	2010							2011										
Actions	**JUI**	**JUIL**	**AOU**	**SEPT**	**OCT**	**NOV**	**DEC**	**JAN**	**FEV**	**MAR**	**AVR**	**MAI**	**JUI**	**JUIL**	**AOU**	**SEP**	**OCT**	**NOV**	**DEC**
Build batteries																			
Battery tests																			
14th ABC presentation																			

Description of the proposing team (as long as needed)

Leader of the project is Dr Carole Lainé, engineer from the ECPM Strasbourg (European engineering school in Chemistry Polymer and Materials) and Doctor in composite materials and polymer from University Lyon 1. Dr Carole Lainé has a professional experience of 5 years in technical textile and especially in PVC plastisols. Dr Carole Lainé works for Amer-Sil for 9 months but, as R&D Manager will lead the project with the help of Urbain Lambert (Director of Technology) to learn more about battery testing. Dr Carole Lainé has published 4 articles in different international scientific journals.

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"Viscoelasticity and Mechanical Properties of Reactive PVC Plastisols" , Polymer engineering and science, vol. 49 (2009), n°6, pp. 1089-1098

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C. Lainé and P. Cassagnau
"Prediction of Zero Shear Viscosity of Poly (Vinyl Chloride) Plastisols" Applied Rheology 16:3 (2006) 136-144
Dr Carole Lainé will be the project manager and privileged interlocutor for the TA Infrastructure.

The technical expert for Amer-Sil will be Urbain Lambert , DiplomChemiker of the Ruhr University of Bochum who works for 33 years in Amer-Sil. Urbain Lambert is Director of Technology and has published one scientific article but has granted 5 patents. Urbain Lambert has a strong experience in battery testing and has helped to define the batteries to be tested and the test procedure. He will participate in analysing the batteries test results.

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