*Sociocultural Dimensions of Technological Learning**

HEBE VESSURI and MARIA VICTORIA CANINO

This paper discusses technological learning in the oil sector in Venezuela, with the help of a case study of ORIMULSION®, which heralded a very important technological breakthrough for the evolution of the nationalised oil industry in this country, being at the same time a challenge and an opportunity.

The technological R&D policy for heavy and extra-heavy oils and bitumens of the Orinoco Oil Belt created the conditions for the domestic system of innovation in the oil industry to realise a catching up process, taking advantage of the available opportunities: the geological wealth offered by the national subsoil, a small but growing scientific and technical community of practitioners having direct access to operational activities of the newly nationalised industry, and an institutional learning procees based on an original technological trajectory both in INTEVEP, the oil industry's technological research centre, and in the domestic operating firms.

The paper traces the complexity of the learning process at different times and in a number of dimensions, with an emphasis on the mechanisms through which the researchers, technicians and managers acquired and/or improved their know-how:

THIS PAPER FOCUSES on the problem of technological learning in the oil sector in Venezuela, as illustrated by a case study of the development of ORIMULSION®. The development of ORIMULSION® was an important technological breakthrough for the evolution of a nationalised oil industry in Venezuela, being at the same time a challenge and an opportunity. It created the conditions for the domestic system of innovation in the oil industry to realise a catching up process taking advantage of the geological opportunities offered by the national subsoil, a practitioners' community and an institutional learning process based on an original technological trajectory. We trace the complexity of the learning process

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The Venezuelan Oil Industry after Nationalisation

Venezuela is a country in the Western Hemisphere with the largest oil reserves, the second largest deposits of natural gas, and the largest reserves of extra-heavy oil in the world.[1] In the 1970s its oil industry (by then still in private foreign hands) was almost totally dependent on foreign technology, with no connection to the country's domestic technological capabilities.[2] For 60 years, foreign oil companies had extracted and marketed Venezuelan oil through concessions. The government's refusal to grant new concessions since 1959 spurred nationalisation, which was inevitable since the country depended on oil exports for 70 per cent of its foreign exchange. In view of impending nationalisation, the new investments needed for upgrading Venezuela's big refineries had not been made.

As things stood, not only would Venezuela not be able to market its large reserves of residual oil externally, but it would also not be able to satisfy the growing domestic demand for gasoline. Since exploration activity had decreased significantly in the previous fifteen years, the common expectation was that the light oil reserves would soon be exhausted and Venezuela would need to use enhanced oil recovery and would need more advanced technology to develop new areas in the Orinoco Oil Belt and the Offshore Continental Shelf to maintain production.

When nationalisation of the oil industry occurred in January 1976, it was decided that the new Petróleos de Venezuela C.A. (PDVSA) and its operating oil affiliates, would have an R&D centre to ensure access to technology from the parent companies of the local concessionaries and other oil firms as well as specialised service companies. As could be expected, when the idea of having such a centre was first mooted[3] in the early 1970s the foreign concessionaries did not pay any attention to these plans. 'The idea of the new Venezuelan R&D centre was considered by some as a "joke"', recalled INTEVEP'S Vice President N. Barroeta.[4] The new centre, INTEVEP, was established under the auspices of the domestic oil industry. The bulk of the Venezuelan Institute of Scientific Research (IVIC)'s Centre of Petroleum and Petrochemistry—78 researchers plus support staff—which had the largest concentration of R&D capacities in the still fledgling national scientific community, moved to INTEVEP.[5] In 1979 INTEVEP acquired its current profile as an affiliate of PDVSA, organised as a commercial enterprise and run as an oil company. This has been a source of constant tension throughout its institutional history. In order to be accepted in the 'oil club', the institute had to relinquish a good deal of the flexibility and long research lead times on basic research characteristic of the creative work carried out in research institutes. Besides, a cultural problem of Venezuelan society victimised INTEVEP for quite a while. Its researchers and higher management officials say that they had to overcome the dominant notion that what is foreign invented is better than anything locally produced.

When INTEVEP was established, there were only 20 hydrocarbon researchers in the country. In 1994, the Institute's 1,634 employees were distributed as shown in Table 1.

TABLE 1
Staff Distribution, INTEVEP, 1994

a) In Terms of Qualification	
Non University	767 (47%)
First Degree (Lic. or Eng.)	532 (32.5%)
MSc	208 (12.7%)
PhD	127 (7.7%)
b) In Terms of Function	
Scientific/Technical	971 (59%)
Technical Support	419 (26%)
Management	244 (15%)
Total	1634 (100%)
c) By Type of Activity (in man/hours 1993)	
R&D	36%
Basic Research	5%
Specialised Technical Services	19%
Engineering	5%
Internal Services	29%
Training	4%
Others	2%

Sources: INTEVEP, Staff Division, *Internal Report*; INTEVEP, *Summary of Activities*, 1993, 1994.

These figures show an enormous increase, although in terms of qualified staff the Institute is still below international standards.[6] To create and consolidate an oil research centre in a developing country is not an easy task. Even within the domestic industry, INTEVEP has not always been given the importance it deserves.[7] Although the institution was established 19 years ago, it was in its 1993–2002 Business Plan that the parent house, PDVSA, included for the first time the technological aspect within its business strategy, not merely as an activity but framed within the business chain. On the other hand, it must also be understood that its researchers and technicians had direct access to the fields and wells and so they often compensated their lack of higher training with the actual possibility of experimenting and 'playing' with the exploratory wells of the Oil Belt.

Venezuela is specialised in oil exploitation. From the early days of the nationalised oil industry in the second half of the 1970s, one of the key problems was the development and/or adaptation of new and existing technologies for the extraction and improvement of heavy and extra-heavy oils from the Orinoco Oil Belt (in Spanish *Faja Petrolífera del Orinoco*). Since its inception, the Belt has represented 50 per cent of INTEVEP's projects portfolio.

In the Beginning there were Emulsions

It is unlikely that the process of stabilising ORIMULSION®[8] as a socio-technical design is complete. However, its physical makeup has a fairly constant socio-scientific design. Further, it has already emerged as a 'new fuel' in the world energy market, a rare occurrence in contemporary history, particularly when it has the potential of making a significant impact on such a major fuel consumer as the electricity industry.[9] What is most unexpected is that this technological development has taken place in a developing country with an infant domestic oil industry and hardly a scientific tradition.

In the early 1980s, the problem faced by the Venezuelan oil industry was not to discover a new fuel but to find an economically viable solution to the problem of transporting through pipelines of heavy crudes and bitumens located in the Orinoco river basin, in southeastern Venezuela. The initial stages of development of a suitable transportation scheme through an appropriate emulsion formulation were carried out at the laboratory level. People were working on the so-called conventional methods: application of heat, diluents, 'annular flux', etc. Part of the research was conducted in collaboration with local universities and through a three-year collaborative research agreement with British Petroleum (BP) Research International into formulating oil-in-water emulsions and transporting them.[10] This early work was probably the result of personal contacts between some INTEVEP and BP officials.[11]

At that early stage, a young graduate of chemistry, Ignacio Layrisse, joined INTEVEP and was sent to Sunbury (near London), to BP's Research Centre. Although he was no expert in the field, Layrisse has emerged as the earliest leader of ORIMULSION®, pushing the project through to fruition with decisions that involved risk taking, creativity, conviction and audacity; sometimes judged by others as irresponsible but being a typical stereotype of a pioneering leader (Shapero 1985). Perhaps he moved too fast, but had he not acted as he did, the project may still be in the stage of mixing the bottle, or the operating firms would have abandoned the project long ago. He managed to agglutinate a team mostly comprising chemists with enormous mystique. Many mistakes were made, and probably some could have been avoided, had people known better. However, history is not made of counter-factuals. In Morichal the craziest experiments were carried out. But it may also be argued that the problems faced by ORIMULSION® could not have been imagined before they were observed *in situ*, and they managed to solve them first empirically, then scientifically.

Towards the end of 1984, the emulsion group achieved its first breakthrough. The group was able to size the emulsion in a controlled fashion with low mixing energy, achieving a significant viscosity reduction with good stability. The story of this achievement is well worth recounting because it provides telling insights both as to the factor of 'domesticated' chance in scientific/technical discovery and the relative lack of expertise that some of the team workers had at the time when the early breakthroughs occurred.

The key actor in this episode was a young Venezuelan female chemist (Maria Luisa Chirinos) who had done B.Sc. in environmental chemistry from Birmingham and had joined INTEVEP upon the completion of her undergraduate studies. There she was assigned the task of measuring bitumen viscosities from samples of crudes emulsioned with sodium hydroxide and with different surfactants, sent from exploratory wells all over the country. The INTEVEP research group was able to obtain a fluid that could be transported, but did not understand its rheology, nor how its viscosity was going to behave. They realised that since an emulsion comprises droplets of something suspended in something else, the size of the droplets was fundamental but none of this they could control. They formed emulsions and put them in bottles, some of which exploded within three days and others within three months, but they had no explanation for any of this. At this point Chirinos was sent to Sunbury with the instruction to learn about interfacial properties, in order to understand the viscous behaviour of those emulsions and control them.

Although she had no advanced training, in view of her practical experience after having tested countless samples of emulsions in Venezuela, she tended to rely on her intuition and on her empirical understanding of the physical phenomenon, which exhibited a number of observational parameters. For example, she realised that the speed with which she mixed the emulsion, the amount of surfactant used, the temperature at which the tests were made, counted, although at the time she did not know why. There was something in particular which attracted her attention, and it was that everywhere in the literature she had found the recommendation that emulsions needed intense, high energy. One evening, someone had left a domestic electric bake mixer to be repaired in the lab. Following a sudden impulse she decided to use it to make emulsions. She measured the water, the INTAN® surfactant (developed by other co-workers in INTEVEP), measured the bitumen and turned on the mixer at low speed, at room temperature.

In her words, she obtained 'an emulsion that seemed like chocolate mousse, so pretty, dark brown, opaque, and not brillant black' as the emulsions she had seen so far. When she put the sample under the microscope, she discovered that almost all the drops were of the same size. She had never seen this earlier, because there were always some big drops together with tiny ones. In this emulsion, by contrast, all droplets were small and similar in size. She spent the whole night trying out different formulae and prepared a chart for producing droplet sizes at will. The next day, when she showed her results, everyone was enthusiastic and the blackboards were covered with formulae. The time for scientific explanations had begun.

BP has narrated this story differently,[12] but the patent belongs to both INTEVEP and BP and Chirinos's name was finally included in it. This form of mixing is called high disperse phase emulsion (HIPR) and even today it continues to be the basic technology used for ORIMULSION®. Other INTEVEP researchers (Hercilio Rivas) are trying to find an less energy intensive alternative technology.

From 'Mayonnaise' to ORIMULSION®

The optimistic outlook stimulated by the early successes suffered a setback with the 1984–85 oil crisis. Oil prices fell sharply, giving rise to a new scenario for ongoing research. Upgrading projects for the Oil Belt for a while lost their appeal and arguments in support of emulsion work were greatly reduced. However,

> the Venezuelans were always keener than the Canadians to find a commercial outlet for their vast bitumen resources. They saw that producing an additional, competitively priced fuel for power stations, had the potential to transform their beleaguered economy and make up some of the revenue lost by falling oil prices since 1986 (Zlatnar 1989: 12).

With the new economic boundary conditions, an alternative horizon had to be rapidly defined, lest the initiative would lose momentum. Fortunately, what had become a precarious path of emulsion research (conceived so far only in terms of transporting bitumen, as fluid mechanics projects) took a saving departure with the aid of another Orinoco Belt related initiative, that of INTEVEP's combustion group.

This team had been working on direct bitumen firing virtually since the beginning of emulsion activities. The use of bitumen as a fuel appeared attractive to one of the domestic oil operating companies, Lagoven. Lagoven's Orinoco Project was driven, among other things, by the interest evinced by the Japanese trading giant Mitsubishi Corporation, as part of Japan's strategy of diversifying its energy resources.

As already mentioned, the initial research problem the emulsion group attacked was how to get the very heavy oil from the bottom of the wells in the Orinoco Basin and transport it to a more convenient location in a port, closer to the refineries. The procedure applied was water plus surfactants injection. The resulting emulsions had, among other things, a high salts content but did not have a high stability, because the purpose was to separate the emulsion again into water and bitumen after reaching its destination. Through the internal collaboration that ensued between the emulsion and combustion groups, it was suggested to burn bitumen as an emulsion. A new set of requirements were defined: the fluid should last for a year or more, withstand handling through pumps and pipelines at high shear; burn as a conventional liquid fuel, similar to fuel oil; and be free of contaminants such as Sodium. Admittedly, INTEVEP's combustion group had identified prior art in the realm of fuel emulsions. The Brazilian oil company (Petrobrás) had conducted emulsification tests with oil-residue-in-water emulsions (Furtado 1994). However, that initiative was never tried on a large scale. And the combustion group's basic idea was derived from its own prior expertise with a small pilot plant for combustion at INTEVEP, in connection with the Venezuelan/German project that sought to avoid vanadium corrosion when fuel oil is burnt.

Domingo Rodriguez, the combustion group's leader, used the carbon–water mixture as a background model, and by analogy with the group's previous work tried to add salts different from Sodium that could act like Sodium but that could be beneficial for combustion. Magnesium, the additive used as a countermeasure for vanadium corrosion, replaced Sodium and helped the emulsion.

In July 1985, the first combustion trial took place with an emulsion which most probably had between 35 per cent to 40 per cent water, much more than what is seen today (30 per cent).[13] Of course, this emulsion was not yet ORIMULSION®, it was still a long way from becoming a fuel. Nevertheless, the public enactment of the combustion of the emulsion caught the imagination of some relevant people at the operating company Lagoven, particularly

Manuel de Oliveira who from then on would lead what came to be known as the Orinoco Project in Lagoven. At this time, the two research groups from INTEVEP—the emulsion group and the combustion group—began to work together, also under the umbrella of the INTEVEP Orinoco Project. The name ORIMULSION® was coined around this time, on the occasion of the visit of a US advisor on patents, indicating the people involved in the Orinoco Project and the emulsion group, which so far had been quite independent. Along with the name, were listed the specifications that would characterise ORIMULSION® as a fuel. Small pilot plants were built in Jobo and in Morichal to enable the testing of the fuel in combustion plants with a higher capacity than INTEVEP's, so that the features of this new fuel could be better analysed. In the latter part of 1985 and early 1986 almost all the heavy work was concentrated in mounting pilot plants capable of producing an emulsion with the required features. The pressure for commercialisation was enormous and it became a burden, because the product as such was not yet in place, there were several steps missing.

Crisis and Redefinition of the Problem

When ORIMULSION® produced at the new 10,000 barrels plant in Morichal (EPM-1) started to be bombed to the terminal station of Punta Cuchillo in Puerto Ordaz some 70 km away, the product exhibited a steep viscosity increase soon after its preparation, which was called 'aging'. It was observed that when the emulsion remained a long time in almost static condition, its viscosity went up remarkably. While production was limited (for demonstration purposes) the emulsion was placed in barrels that had to be moved for transportation to different destinations. Once transported, the emulsion returned to its original state and thus the phenomenon was not visible. But when the emulsion was transported through a pipeline with a large diameter, due to the low speed within the oleoduct the central part of the emulsion was almost static, for it was not subjected to the cutting force or it suffered only a little cutting effort, and the phenomenon of 'aging' became visible. This effect was so severe in Morichal that it was almost impossible to pipeline the fuel to the dispatching terminal. It was equally impossible to continue the combustion evaluation. Commitments had been made with demonstration trials. The whole project was in jeopardy.

This is a known effect in emulsion science, by which a fraction of the continuous phase (water in this case) is diffused into the bitumen drops (the disperse phase), swelling them and artificially creating a more concentrated emulsion with its associated higher viscosity. This is what is called a multiple emulsion, that is, a water-in-oil-in-water emulsion. Little, if any, scale up considerations were made. If the people in charge had possessed complete knowledge of the rheology of the product, the problem could have been avoided. But since they did not possess complete knowledge, the attempt to produce more ORIMULSION® was accompanied by this major setback.

Why did this happen? In 1986 it was obvious that Lagoven was leading the project, for they already had established a marketing branch and a process development branch for manufacturing the emulsion. Indeed, the Orinoco Project at INTEVEP was fragmented and I. Layrisse was sent to Morichal to be in charge of field operations along with Lagoven. D. Rodriguez was no longer the manager of the Orinoco Project but of a programme of residuals evaluation. The two INTEVEP projects (emulsions and combustion) were soon separated once again. Indeed it gives the impression that INTEVEP ceased to lead technological development on behalf of Lagoven, for as an organisation, Lagoven was much more aggressive in establishing its leadership in this project. But, Lagoven is a company without a background in development activities. Maybe things would have been more under control if technological development had remained with INTEVEP, which had the requisite expertise.

On the other hand, it is also true that emulsification is a process which is normally done in batches. To do it in a continuous way requires a certain know-how that was not available at the time, at least to the people in charge in Morichal. The lack of a team of process engineers and of chemical engineers in the scaling-up stage caused many difficulties. Why were process engineers not involved? We may only hint at some explanations for this. Most of the people who worked on emulsions were chemists. Process engineers are usually involved in refining and petrochemistry. In the case of ORIMULSION® one may guess that there was an oversimplification of the scaling-up process by the concerned chemists, an underestimation perhaps because of lack of experience in this field by the people who led the work at the time.

The ORIMULSION® Technology Comes of Age

During a very intense period of analysis, trial and error, the problem was provisionally solved in an empirical way, adding certain electrolytes to the emulsion, a solution that worked as often as it did not.[14] One of INTEVEP's researchers, Hercilio Rivas, while in Britain as technical advisor of the group that was trying to introduce ORIMULSION® in European markets (1987–88), did some bibliographic research and was able to offer a scientific explanation for the problem in osmotic terms. ORIMULSION® was, in fact, a multiple emulsion. The aging effect stemmed from the down-hole emulsification procedure. After lifting, the 'primary emulsion' would go through a separation stage. Brine was added to facilitate this, owing to the closeness of the density values of water and bitumen. Moreover, the down-hole emulsification would contain some reservoir water, also rich in salt.[15] When this hydrocarbon was then emulsified into ORIMULSION®, the dispersed drops would contain tiny brine drops, inducing an osmotic imbalance, responsible from the substraction of continuous phase and the increase in viscosity.

But overlooking the scaling-up dimension not only led to a crisis with regard to 'aging' of the emulsion. There was another grave problem linked to the process stability, because the mixing systems used at an early stage were not adequately chosen due to ignorance of certain aspects of the process. It may be argued, though, on behalf of Venezuelan researchers, that in addition to the usual handicaps of working in a developing country, this was the first time in the history of the oil industry that this process was being carried out. The experience in mixing does not exist in the world as knowledge one acquires in a graduate programme. The people who do mixing usually have a background in fluid mechanics and acquire their specific know-how through practice. The 'aging' setback prompted the inclusion of scale-up people. To scale-up the second generation of ORIMULSION® (EVC technology, for controlled viscosity emulsions), produced by Hercilio Rivas and his group (with a patent already granted), the mixing factor appeared to be critical, after some previous flat failures of mixers bought without any technical considerations. A high INTEVEP/Lagoven official (Reinaldo Ceballos) contacted TKK, a small Japanese family firm with long experience in mixing equipments, and an agreement was signed for a joint project aimed at understanding the mixing technology required. The local counterpart was Gustavo Nuñez, a young PhD in fluid mechanics with Daniel Joseph in Minnesota, who spent the following years making visits to Japan.

The Japanese, however, were unable to solve the problem posed by the emulsion but they sent to INTEVEP all their line of mixers which were tested in Venezuela. On the basis of the failures that were found in *in situ* trials and because the studies and bibliographic reviews made showed that in order to produce those emulsions there was no adequate mixing equipment available in the market, Nuñez's scaling-up group from INTEVEP designed the equipment which was finally named ORIMIXER®. TKK admitted the development to be a success and the ORIMIXER® patent belongs to INTEVEP. ORIMIXER® is commercially manufactured by TKK on the basis of INTEVEP's design and patent. Today the EPM-2 plant has a capacity of producing 100,000 barrels of ORIMULSION® with the ORIMIXER®, which has obviously given good results.

Chain of Crises, Chain of Solutions in the Learning Process

It could be said that the three fundamental factors that have contributed to the success of ORIMULSION® were: the HIPR technology, which history has proven to be a solid achievement, since the fomulation of the emulsion has changed very little with time; the scientific discovery of the causes of 'aging'; and the ORIMIXERS® which have contributed to stabilising the process.

In this view, the remaining achievements are by comparison secondary issues. An alternative way of looking at this development, however, is by realising that the aging problem was not the first nor the last one. Different process related difficulties appeared in a seemingly endless stream of setbacks. One way or another they were solved and became rites of passage which induced further progress. The aging problem generated knowledge; a cost related change in the down-hole emulsification scheme led to a diluent infection and removal procedure; and unstable mixing dynamics and lack of repeatability led to the design of a 'tailor-made' mixing unit. The list continues. All this has led to second and third generations of ORIMULSION® fuel and has consolidated the current manufacturing.

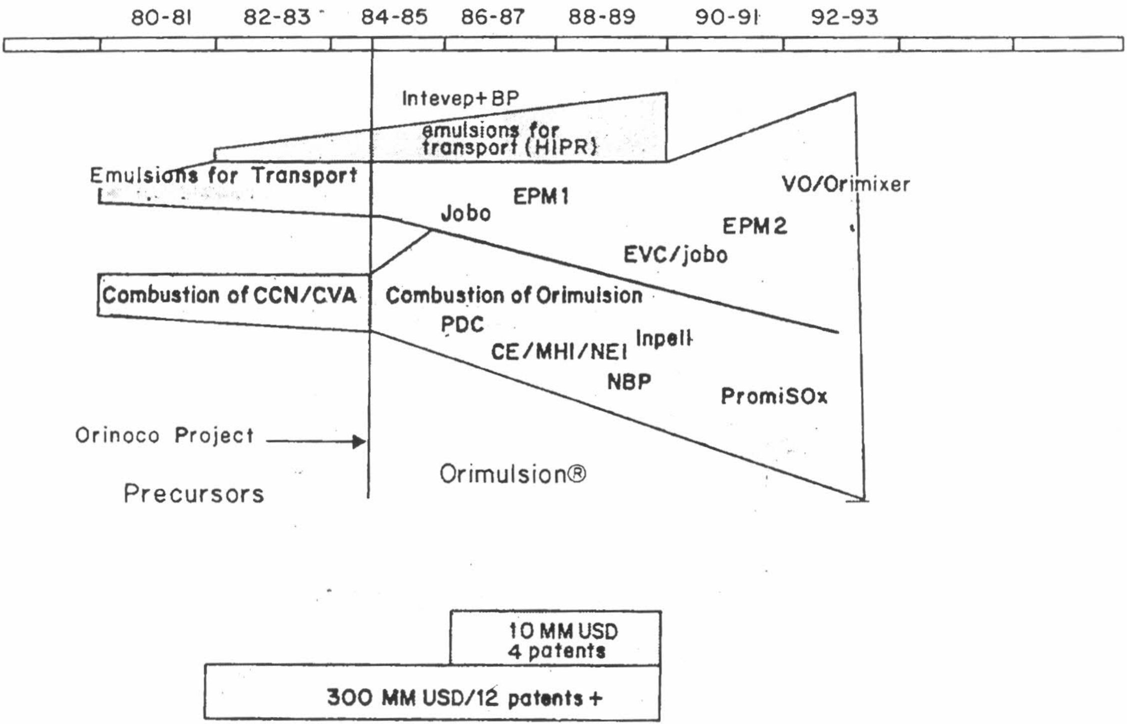
Gradually, through several partial redefinitions of the problem, 'closure' has been achieved (Pinch and Bijker 1987: 44–46). The meaning of the initial transport emulsion was translated to constitute a solution to another problem: one of producing a new fuel. And by redefining the key problem with respect to which the artifact should have the meaning of a solution, of course closure was reached for some of the potentially relevant social groups. ORIMULSION® was conceived to fill a market niche. The target was to establish it as a non-conventional fuel that could be burnt in conventional power plants, as an alternative to coal and high sulphur fuels, with minimal changes in the burners. It would have to be delivered to international markets in conventional oil tankers, being a fuel with high combustion efficiency, high heating value, and a very stable clean burning flame. Last but not least, it would have to ensure an unlimited supply of feedstock, hundreds of billions of barrels of Orinoco oil/bitumen.

Clearly, many lessons have been learnt by the institutional collective in the development of ORIMULSION®: after the passion of the short term, a more detached analysis permits realisation of the importance of pioneer leaders capable of inspiring others and of making things happen despite the fact of being newcomers to an emerging technology and the lack of experience, knowledge and legitimacy. Relevant social actors at different times created specific conditions for success. Nevertheless, they also learnt that the development slope was a steep one. The process of technological development was so timed that it proved difficult to change. The marketing window of opportunity was not matched with the technological readiness.

Marketing proceeded much faster than technological development, arousing the premature enthusiasm of some officials and leading to undue oversimplification of technological development, that eventually struck back. Probably, if the ORIMULSION® group had known better when they embarked on it, they would have spent the same time to do it but in a less traumatic way.

They also learnt that multidisciplinary teams must be created early, particularly with regard to scale-up. Technological practice

Development of Orimulsion®



is dominated by well-defined practitioners' communities that encapsulate technological cognition. However, in defining a cognitive universe, the specialised community of practice inhibits recognition of radical alternatives in the technological practice (Constant 1984: 28–31). Abrupt transitions in technological practice tend to occur as a result of outsiders' actions (as when the combustion practitioner group and the process engineer practitioners translated the ideas of the emulsion group).

Manage support of R&D projects also proved to be crucial, specially where the results of research were not predictable. Professional, marketing and operational mechanisms have to be forthcoming. PDVSA has created more recently BITOR, a new affiliate to commercialise ORIMULSION®, which appears to have an ever increasing market share.

In this learning process, Venezuela has emerged as the country that has the most knowledge about heavy crude oil and bitumen.

NOTES

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1. With 62 billion barrels, Venezuela ranks sixth after Saudi Arabia (260), Iraq (100), UAE (98), Kuwait (97) and Iran (93). However, considering the country's vast deposits of heavy oil in the Orinoco Belt—recoverable reserves of which are estimated at over 250 billion barrels—it will no doubt continue to play a key role in shaping the future of world oil and energy prospects (Brossard 1993: XV).
2. The small labs that the foreign oil concessionaries built in Venezuela after the Second World War were for research in exploration and upstream operations, and not for downstream operations. When they began to build their large expensive research labs in the United States, they closed down most of their small overseas labs.
3. A work group appointed in 1970 under the auspices of the newly created National Science Council (CONICIT) made a 'National Research Program on Petroleum and Petrochemistry', and recommended the creation of a Venezuelan Institute of Petroleum to carry out applied research, technological development and engineering.
4. Personal interview with Dr N. Barroeta, when he was Vice President of INTEVEP, 1994.
5. IVIC was founded in 1959 and in the 1970s was the single scientific research institution in the country. See the report by UNESCO Mission (1972). See also Vessuri (1996).
6. In the country at large, there are still strong deficits in qualified human resources in chemical and petroleum engineering.

7. Interview with Francisco Pradas, President of INTEVEP, NOTIVEP (March–April 1995: 2–8).
8. ORIMULSION® consists of basically 70 per cent natural bitumen of 7–10 API gravity, 30 per cent water and a commercially available surfactant, nonyl phenol ethoxylate, which is added to stabilise the emulsion and prevent the water and bitumen from separating. However, the process is not as elementary as it sounds because one of the key factors enabling ORIMULSION® to achieve its high combustion efficiency rate of 99.9 per cent is the small size of the bitumen droplets in the emulsion. Each need to be about 20 microns or one-fiftieth of a millimetre in diameter and evenly distributed in the water.
9. In order to avoid confusion or association of ORIMULSION® with the conventional oil market, and since it is seen as a direct competitor with steam coal, PDVSA has since the beginning of the project referred to ORIMULSION® as a 'non conventional' fuel with the official volume measurements given in tonnes rather than barrels (Zlatnar 1989: 13).
10. They were searching for an alternative and more economical production and transportation method other than using heat and adding expensive diluents (which could be either a lighter gravity crude oil or a naturally occurring gas condensate) to reduce the viscosity (Zlatnar 1989).
11. David Graham of BP and Leon Mandell of INTEVEP, were some such early figures.
12. According to the local anecdotary, the British argued initially that the idea belonged to the domestic mixer's owner! Fortunately the Venezuelan girl had her laboratory notebook and she had even taken pictures of all the emulsions she made. Finally, the lawyers decided that she had something to do with it and had to be included in the patent.
13. The emulsion people were working on such a small scale that even for the firing test they had to make a 'salad' of all the small samples that were available at the time.
14. Apparently, Mitsubishi which was the customer at this early stage had also detected the 'aging' problem and corrected it, probably simply by 'massaging', mixing the emulsion. According to a personal communication of a researcher, Mitsubishi used this tool later as a negotiating factor and said that it had the technology to do it.
15. Typically, bitumen was dehydrated up to 2 per cent w/w water (brine).

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