



Oil & Gas Technology

Equipments, Materials & Corrosion

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PREFACE

NeuroNAC® JIP

*Development of Innovative & Reliable Models for Crude Oil Qualification
Corrosivity Classification & Effect Prediction*

NeuroNAC® JIP in a few numbers

1 Year of Preliminary Study performed in 2010

3 Years of Laboratory Testing

1000 Tests

72 Blends Typologies

(from barrels of crude oils provided by Participants)

1 Oil Qualification Tool

1 Corrosion Rate Prediction Tool



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INTRODUCTION

Since the Naphthenic Acid Corrosion (NAC) phenomenon was identified in the 1920's, it is still continuing to be a lived great issue for the petroleum industry.

Its highly detrimental effect is even yearly emphasized as the opportunity crudes market keeps on growing irretrievably while leading to higher TAN crudes and blends processing.

The naphthenic acids, reacting with the iron species contained in steel, lead to the formation of iron naphthenates which are soluble in oil. As a consequence, the metal surface remains continually exposed to the processed detrimental components and contaminants damaging effects.

Three ordinary counteracting methods are currently implemented in the industry to tentatively face this problem for given process conditions: the proper blending, the use of corrosion inhibitors and the specification of corrosion resistant materials in most critical areas.

At the same time, uncertain approaches have been aimed at building tentative NAC rates measurement/prediction tools via computational parametric models. However, these models remain deterministic ones in which efficiency and suitability remains distrustful. As a matter of fact, it is commonly agreed that linear and parametric mathematical models are not well appropriated to translate such a system involving the complex combination of a large number of influencing (varying) parameters.



SCOPE

The scope of NeuroNAC® JIP is aiming at the Design and Implementation of two reliable numerical tools: instruments for crude oils (or blends) inherent corrosivity qualification and corrosion rate prediction.

The first one will enable knowledge of blends shifts consequences while:

- ☛ **Assessing** oil relative corrosivity
- ☛ **Classifying** crudes (or blends): low/medium/high corrosivity

Whereas the second one will enable the petroleum industry to self-manage the situation while:

- ☛ **Predicting** crudes (or blends) effects and the estimated corrosion rates
- ☛ **Anticipating** proper counteracting methods

It will then become practicable to simulate a given situation and its effects on corrosion rates; the induced results will give valuable information to operators to optimize their processing operations and associated spending.

- ☛ To achieve this goal, it has been decided to propose an **innovative approach**.

The fruitful collaboration of ENI and UNIMI (Ref. to '*Study of Naphthenic Acid Corrosion by Neural Network*', S.P. Trasatti and G. Gabetta, Corrosion Engineering, Science and Technology 41, 2006) stated: '*The neural network model can perform extrapolation and interpolation operations for materials selection purposes or to predict corrosion rates as a function of the operating conditions*'. The development of such computational models will



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be the ingenious aim of the NeuroNAC® JIP project and the basis for both tools mentioned above.

By operating numerous and varied influencing parameters through a duly trained and customized ANN, the players will then be able to translate the real situation regarding anticipated corrosion rates while even assessing the effects of variations among given parameters.

PROPOSITION

The NeuroNAC® JIP idea came up to provide Oil & Gas Industries opportune and reliable means to assess more accurately crudes (or blends) corrosivity and predict corrosion rates. On the one hand, this will permit to lessen the undergone failures and damages through adequate blendings and, on the other hand, this will result in a safer and more effective use of acid crudes.

As regards to its complexity level, the NAC phenomenon is not fully understood yet (notably because of interactions between the great numbers of involved parameters, the action of some sulphur compounds, the process flow hydro-dynamic effects, etc.).

Deterministic computational approach appears to be neither efficient enough nor applicable as it only allows one influencing parameter change at the same time.

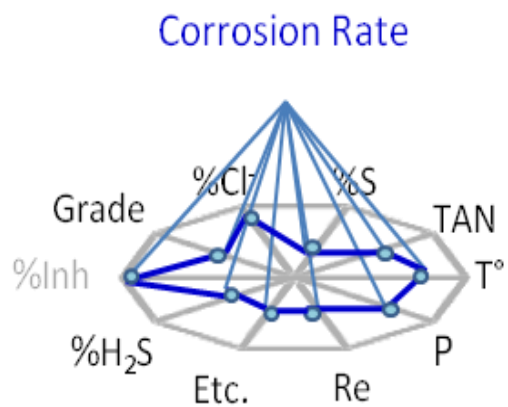
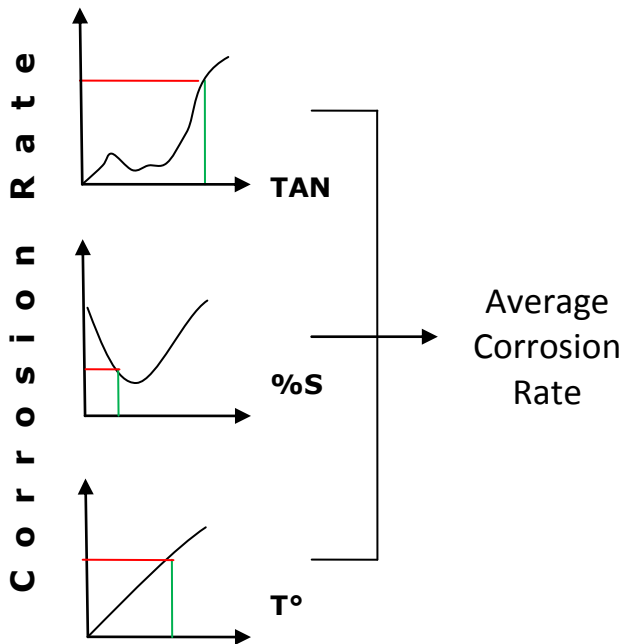
That is why neural networks come into the picture: these networks can detect trends that are too complex to be noticed either by humans or other computer techniques. This is the undeniable and established superior capability of such an Artificial Intelligence to do so for highly demanding applications (Ref. to *Appendix B*).



DETERMINISTIC APPROACH

vs.

NEURAL NETWORK APPROACH



To become an astonishing tool, an Artificial Neural Network needs a reliable database covering representative variations. This will be performed by a wide range of laboratory corrosion tests conducted with blendings of crude oils supplied by Participants.

This testing phase will be divided into two parts matching the setting up of the crudes (or blends) corrosivity qualification instrument (NeuroNAC[®]-Scale) and the corrosion rate prediction instrument (NeuroNAC[®]-Ware).

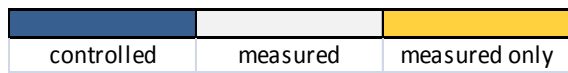


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NeuroNAC®-Scale

After having substantially characterized many different crudes (or blends) in physico-chemical properties terms, corrosion tests will be performed for a given hydrodynamic configuration and given process parameters. Only the temperature will vary, as main referencing process parameter for oil inherent behavior. 9 parameters will be studied, among which 6 main will be duly controlled alternately to cover wide variations, and 3 (as less influent) will be measured only.



	P1	P2	P3	P4	P5	P6	Pi	Pj	Pk
OIL 1	[a :z]								
...									
...									
...									
...									
OIL 72									

NeuroNAC®-Ware

Hydrodynamic conditions and process parameters (in addition to physico-chemical properties of blends) will be incorporated in this model, as it is well-known that the NAC phenomenon is greatly depending on those hydrodynamic effects. 4 steel grades will be studied. The different combinations of the parameters will be established randomly.

	P'1	P'...	P'k
500 different random combinations	X1	X1	X1
	X2	X2	X2
	X3	X3	X3
	X4	X4	X4
	X5	X5	X5
	X6	X6	X6
	X7	X7	X7

A benchmarking phase will enable the selection of the preeminent Artificial Neural Network model. Once elected in between short-listed ANN, the chosen neural network will be duly customized to be the optimum for the specific NAC problem treatment. Finally it will be trained from the database to generate the weighed interactions between influencing parameters and the resulting connections between inputs and outputs.

At the end of this training phase, ultimate testing operation will be performed in order to cross-check the models efficient suitability. This will be the deliverable of the NeuroNAC® JIP which will allow the industrial implementation and use by Participants.

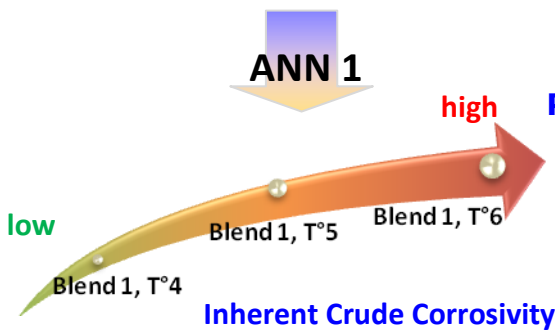


NeuroNAC®-Scale

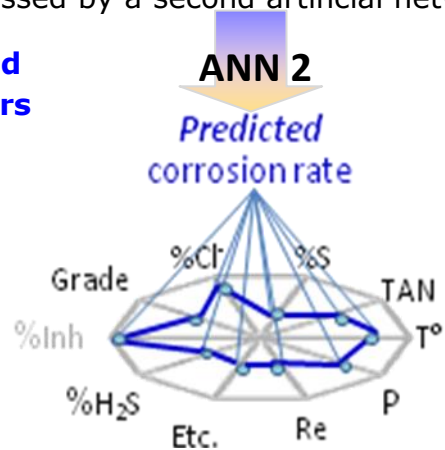
Inputs (crudes (or blends) properties composition, temperature) and measured outputs (relative corrosivity degree) will be collected and put through the first artificial neural network.

NeuroNAC®-Ware

The built NeuroNAC® JIP database will contain inputs (process parameters, hydrodynamic conditions, oil composition, etc.) and measured outputs (corrosion rates). The whole database thus constituted will then be processed by a second artificial network.

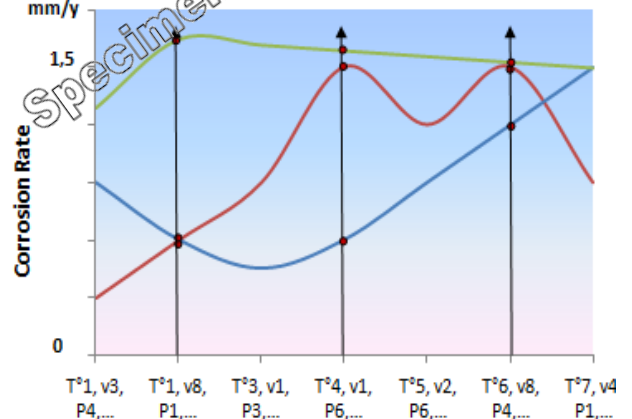
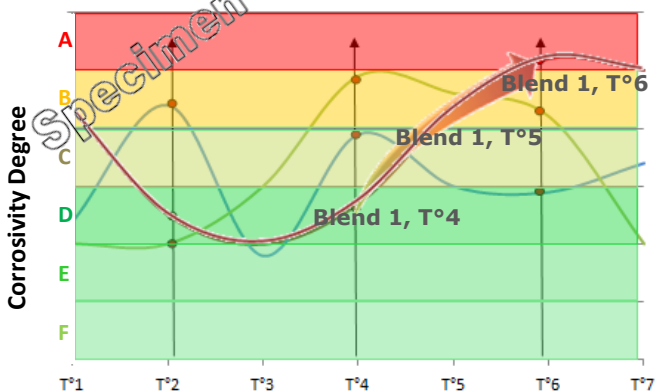


Hydrodynamic and Process parameters varying



An universal scale, qualifying the inherent corrosivity of the crude from its physico-chemical properties and processing temperature only.

A tool allowing corrosion rates prediction from the combined parameters influencing NAC phenomenon in different process conditions.





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GOAL & DELIVERABLES

Once the Artificial Neural Network models developed by NeuroNAC® JIP will be validated as reliable tools for degree of corrosivity assessment and corrosion rates prediction, they will be delivered to the Participants in the form of computational interfaces, with the broad shared and compiled database.

They will have been efficiently trained to be specific to the NAC problem resolution, and, to crown it all, Participants will own the capability to improve and even more customize their ANN by adding their inputs to the existing database.

The stakes will be substantial while meeting Oil Community waitings; among them appear:

- ☛ **The classification** in terms of intrinsic corrosive behavior of the different crudes (or blends) processed by the refiner from their physico-chemical properties and operating temperatures; Inputs for RBI approach.
- ☛ **The quantification** of corrosion rates in regards to plant lived conditions; Inputs for RBI approach.
- ☛ **The estimation** of corrosion rates shifts induced by operating parameters change.
- ☛ **The determination** of the acceptable change for operating windows vs maximum allowable corrosion rate.

By using the Artificial Neural Network models to assess Oil Inherent Corrosivity and predict induced Corrosion Rates, it will be undoubtedly fruitful for oil industries to self-manage and safely process Opportunity Crudes while **challenging cost savings.**



Appendix A: Non Exhaustive List Of References

- S.P.Trasatti (Department of Physical Chemistry and Electrochemistry, University of Milan) and G.Gabetta (ENI Exploration & Production Division), '*Study of Naphthenic Acid Corrosion by Neural Network*', Corrosion Engineering, Science and Technology **41** (3), 2006
- S.P.Trasatti, G.Zangari, '*Artificial Neural Network-ANN: Innovative Modelling Methods – Development and Application*'
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- S.P.Trasatti, '*The Contribution of Neural Networks to Solve Corrosion Related Problems*' Advanced Materials Research, 2010, vol.95, pp.23-26.
- S.P.Trasatti, '*Artificial Neural Network for corrosion control and data management*', EUROCORR 2006, Corrosion in the refinery industry, 26 september 2006, Maastricht, The Netherland
- S.P.Trasatti and G.Zangari, '*Artificial Neural Network for process control and monitoring*', EFC WP15: Corrosion in the refinery industry, 31 March 2006, Porto Marghera, Italia
- '*NeuroAI – Intelligent Systems and Neural Networks*', www.learnartificialneuralnetworks.com
- David C. Silverman, '*Tutorial on Artificial Neural Networks*', www.argentumsolutions.com
- '*Artificial Neural Networks Technology*', www.psych.utoronto.ca
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- A.Turnbull, E.Slavcheva and B.Shone, '*Factors controlling naphthenic acid corrosion*' Corrosion/98 Paper No.579 (Houston, TX: NACE, 1998)
- E.Babaian-Kibala, Michael J. Nugent, '*Naphthenic Acid Corrosion Literature Survey*', CORROSION/99, Paper No. 378 (Houston, Texas: NACE, 1999)
- S.Tebal, '*Critical Review of Naphthenic Acid Corrosion*', CORROSION/99, Paper No. 380 (Houston, Texas: NACE, 1999)
- '*Passing the Acid Test*', Frontiers, December 2001
- R.D.Kane, M.S.Cayard, '*A comprehensive Study on Naphthenic Acid Corrosion*', CORROSION/2002, Paper No. 2555 (Houston, Texas: NACE, 2002)
- R.Riva, G.Gabetta, M.Tolomio, P.Bruni, '*Naphthenic acid corrosion of 9%Cr 1%Mo steel*', Minutes of EFC WP15 Corrosion in the Refinery, March 2004



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Appendix B: Relevant Applications of Artificial Neural Networks

- [Agriculture](#)

*Machine vision for color inspection of potatoes and apples, developed by **American Society of Agricultural and Biological Engineers***

- [Automotive](#)

*RALPH: Rapidly Adapting Lateral Position Handler, developed by **The Robotics Institute, Carnegie Mellon University and AssistWare Technology***

- [Chemistry](#)

*Situs: program package for the docking of protein crystal structures to single-molecule, low-resolution maps from electron microscopy or small angle X-ray scattering, developed by **Department of Pharmacology, University of California***

- [Criminology](#)

*CATCH : Computer Aided Tracking and Characterization of Homicides, developed by **Pacific Northwest National Laboratory***

- [Finance and economics](#)

*Neural Network for trading systems, **Wall Street Firms**
Neural Network for prediction of gas price change, **Northern Natural Gas***

- [Materials science](#)

*Neural network model of creep strength of austenitic stainless steels, developed by the **Department of Materials Science and Metallurgy, University of Cambridge***

- [Technology](#)

*IFCS : Intelligent Flight Control System IFCS, developed by **NASA***

- [Games, sports, gambling](#)
- [Robotics](#)
- [Medicine](#)
- [Music](#)
- [Face recognition](#)
- [Weather forecasting and atmospheric science...](#)