



Ricerca di Sistema elettrico

## Installazione e collaudo di una macchina per Detonation Spray

*Alessandro Gessi*

## INSTALLAZIONE E COLLAUDO DI UNA MACCHINA PER DETONATION SPRAY

Alessandro Gessi (ENEA)

Settembre 2013

Report Ricerca di Sistema Elettrico

Accordo di Programma Ministero dello Sviluppo Economico - ENEA

Piano Annuale di Realizzazione 2012

Area: Produzione di energia elettrica e protezione dell'ambiente

Progetto: Sviluppo competenze scientifiche nel campo della sicurezza nucleare e collaborazione ai programmi internazionali per il nucleare di IV Generazione

Obiettivo: Sviluppo competenze scientifiche nel campo della sicurezza nucleare

Responsabile del Progetto: Mariano Tarantino, ENEA

**Titolo**

## Installazione e collaudo di una macchina per Detonation Spray

**Descrittori**
**Tipologia del documento:** Rapporto Tecnico

**Collocazione contrattuale:** Accordo di programma ENEA-MSE su sicurezza nucleare e reattori di IV generazione

**Argomenti trattati:** Tecnologie dei materiali  
 Generation IV reactors

**Sommario**

I processi di deposizione basati sul metodo Detonation Spray sono di grande interesse per la comunità scientifica LFR, in quanto consentono la deposizione di strati sottili, fino a 20µm su substrati austenici e ferritici. I presente documento sintetizza le attività in corso e completate sul DS presso ENEA Brasimone.

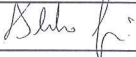

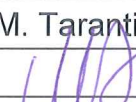
**Note**


Testo in Inglese.

**Autori:**

A. Gessi (ENEA)

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0	EMISSIONE	25/09/2013	NOME	A. Gessi	M. Tarantino	M. Tarantino
			FIRMA			
REV.	DESCRIZIONE	DATA		REDAZIONE	CONVALIDA	APPROVAZIONE

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## PREFACE: THE ISSUE OF CORROSION IN LFR

Lead cooled Fast Reactors represent one of the most promising technologies in the frame of Gen IV fission fast reactors development. The materials' issue is one of the central topics.

In fact, all the high temperatures components (i.e. 550°C) shall be exposed to a flux of liquid Pb with a speed of 1-2m/s, thus leading to high corrosion phenomena. An example of such components is the fuel claddings. A consequence of this environment is that materials should stand a sum of different effects: neutrons and possible swelling, leading to creep and mechanical stresses, corrosion, erosion, chemical interaction with the fuel and the fission products.

There are several different approaches with the goal to face the above depicted problems. One of the most promising is the performance of protective coating layers on top of the exposed components.

In between the many industrial options for coatings manufacturing, ENEA Brasimone chose the "Detonation Spray" method, because of two main important reasons:

- The possibility to spray directly oxides on the substrates with very high densities and compactness
- The simplicity of an industrial system.

This ongoing activity is the very first for ENEA Brasimone, covering the topic of new materials manufacturing, thus representing a very interesting opportunity.

## COATINGS: AN OVERVIEW

Coating was proposed in the past and, in some cases, also tested in nuclear reactors, in order to improve the corrosion resistance or tribological properties of materials used in reactor core and in other vessel internals. Co-based Stellite 6, as wear resistant coating, in French Na-cooled reactors is one example of coatings used in core vicinity. However, up to now the purpose was mainly to mitigate some specific technological issues, rather than to increase safety margins.

Shadowed by the recent Fukushima's accident, the global nuclear industry has to work hard in order to improve the safety and reliability standards of nuclear systems. In this context, for the

next generation nuclear facilities (ADS, research reactors, GENIV-type demo reactors), the researchers are focusing more and more on high-performance coatings and surface engineering.

The last decade development of both coating deposition technologies and of scientific knowledge, concerning chemical composition and substrate adherence, is a strong support for researchers and designers working to enhance safety and reliability of the next generation nuclear facilities.

From previous research activities, the surface modification of fuel cladding materials have been identified as one option to increase the temperature on one side and to increase safety margins (e.g. corrosion resistance) on the other side of future nuclear systems, especially for those cooled with Pb alloys. Reservoir layers containing Al have shown the capability to improve corrosion resistance in Pb alloys significantly. However, so far optimization of coating composition was limited to Al content. Positive effects of adding minor amounts of reactive elements, that have shown their potential in high temperature applications, are not considered and investigated up to know.

In the case of Na-cooled systems at which corrosion is not an issue of concern so far – going to 60 years might change this view. Likewise the replacement of Co-based alloy coatings used for hardfacing some internal components and fretting phenomenon in HEX tubes are the areas where application of coatings are and should be discussed.

A further open topic in general is the use of different coating architectures that have shown in non nuclear application their potential to improve material properties. DS coating is ENEA choice.

## DETONATION GUN SPRAYING

D-gun spray process is a thermal spray coating process, which gives an extremely good adhesive strength, low porosity and coating surface with compressive residual stresses. A precisely measured quantity of the combustion mixture consisting of oxygen and acetylene is fed through a tubular barrel closed at one end. In order to prevent the possible back firing a blanket of nitrogen gas is allowed to cover the gas inlets. Simultaneously, a predetermined quantity of the coating powder is fed into the combustion chamber. The gas mixture inside the chamber is ignited by a simple spark plug. The combustion of the gas mixture generates high pressure shock waves (detonation wave), which then propagate through the gas stream. Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 4000 deg C and the velocity of the shock wave can reach 3500m/sec. The hot gases generated in the detonation chamber travel down the barrel at a high velocity and in the process heat the particles to a plasticizing stage (only skin melting of particle) and also accelerate the particles to a velocity of 1200m/sec. These particles then come out of the barrel and impact the component held by the manipulator to form a coating. The high kinetic energy of the hot powder particles on impact with the substrate result in a build up of a very dense and strong coating. The coating thickness developed on the work piece per shot depends on the ratio of combustion gases, powder particle size, carrier gas flow rate, frequency and distance between the barrel end and the substrate. Depending on the required coating thickness and the type of coating material the detonation spraying cycle can be repeated at the rate of 1-10 shots per second. The chamber is finally flushed with nitrogen again to remove all the remaining “hot” powder particles from the chamber as these can otherwise detonate the explosive mixture in an irregular fashion and render the whole process uncontrollable. With this, one detonation cycle is completed above procedure is repeated at a particular frequency until the required thickness of coating is deposited.

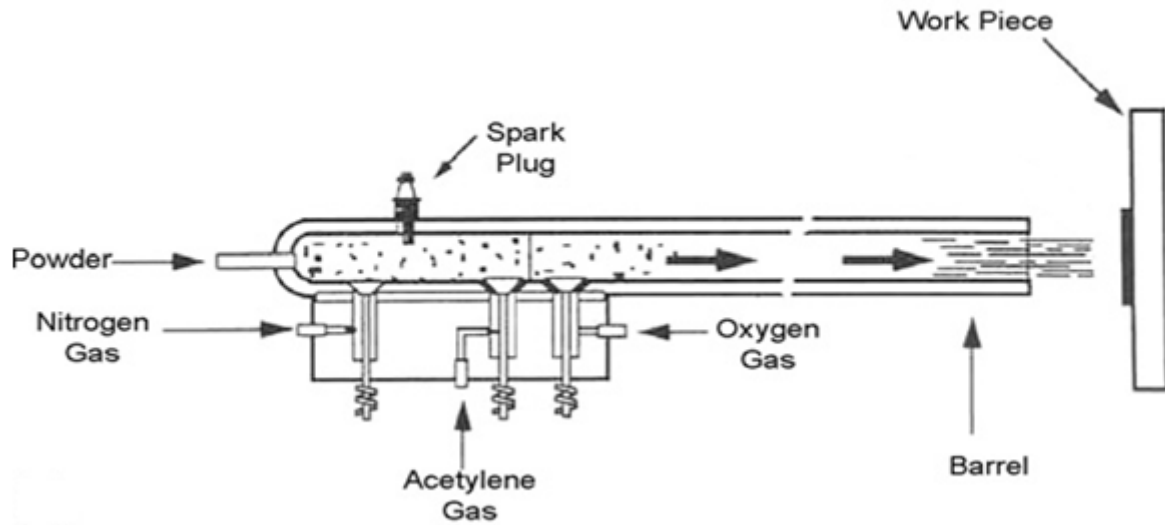


Fig.1. Detonation Gun process

The chamber is finally flushed with nitrogen again to remove all the remaining “hot” powder particles from the chamber as these can otherwise detonate the explosive mixture in an irregular fashion and render the whole process uncontrollable. With this, one detonation cycle is completed above procedure is repeated at a particular frequency until the required thickness of coating is deposited.



## THE ENEA DETONATION SPRAY EQUIPMENT: THE ACTIVITIES CARRIED ON IN 2013

As a first step, at ENEA Brasimone for coating manufacturing, CCDS200 DS coating machine from STPC company, Novosibirsk, Russia, has been purchased and is being installed. It has to be underlined that STPC is the only vendor worldwide of this machine, originally trademark of Praxair ® USA. Together with an installation at Grenoble University, it will be the only European facility DS based.

The chosen experimental hall for DS hosting is located in the so called “ex-lidar” area, where suitable buildings, in terms both of facilities and requested audio insulation, are present.

On the other hand, being this area not used since several years, a huge work of restoration and adaptation has been carried on during year 2013. It is summarized as follows:

- Evictions and demolition of the existing interior flooring linoleum particularly deteriorated
- Remake of a reinforced concrete slab with welded type 815 thick. 15 cm
- Creation of a base in reinforced concrete with steel nets to act fixing with anchor bolts of the machine
- Soundproofing-through suitable panels on the walls and the door to the noise abatement when operating the machine (about 140 db)
- Painting with two-component epoxy resin of screeds previously made
- Supply and installation of the floor of the bathroom floor made of single-fired (tiles?)
- Change of the windows with new shatterproof (one?)
- Supply and installation of a window to check the working area equipped with shatterproof glass
- Creation of an outdoor shed for housing the cylinder bundles
- Masonry for the realization of various holes and passages
- Water connections
- Works adjusting the electrical facilities
- Accomplishments-lines for technical gases and compressed air

The actual shape of the experimental hall and service areas is depicted in fig.2

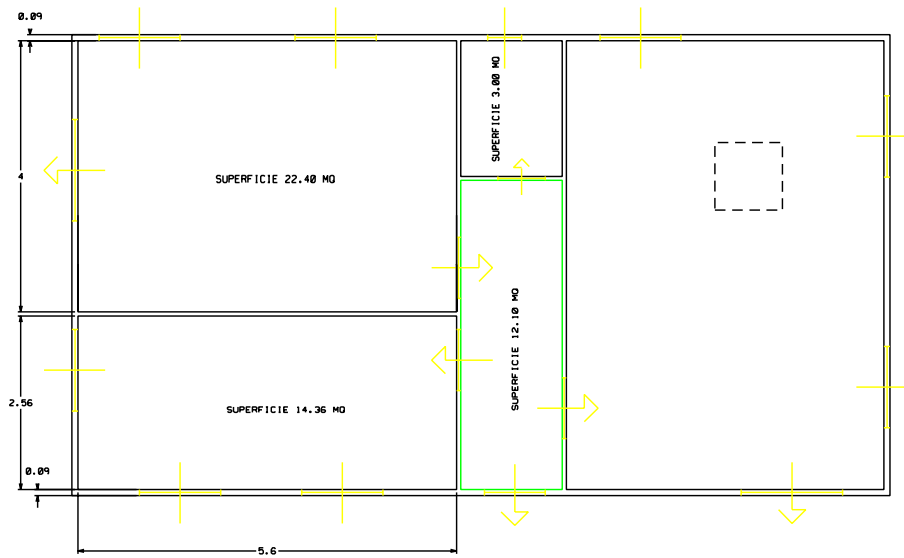


Fig. 2: sketch of the new DS experimental area.

The main goals of this installations follow the requirements of the instrumentation, as depicted in the previous report.

**STATUS: INSTALLATION CERTIFICATIONS AND TEST**

	<b>TEST IMPIANTO</b>	
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**CLIENTE :** ENEA – STAB. BRASIMONE  
**DATA :** 16/09/13  
**DESCRIZIONE IMPIANTO:** IMPIANTO DISTRIBUZIONE GAS TECNICI PER "DETONATION SPRAY"  
**PROGETTO N°:** 600132653

**CONTROLLI E PROVE EFFETTUATE**

CONTROLLO VISIVO	OK
TEST ALLA MASSIMA PRESSIONE DI ESERCIZIO (METODO EMISSIONE DI BOLLE)	OK
TEST STABILITA' DI REGOLAZIONE PRESSIONI	OK
CONTROLLO EROGAZIONE	OK

**NOTE :**

SI E' PROVVEDUTO AD ESEGUIRE LA FORMAZIONE ALL'UTILIZZO DELL'IMPIANTO ED UN TEST DI APPRENDIMENTO PRATICO AL SIG. GRANIERI

PER AIR LIQUIDE ITALIA SERVICE S.R.L. AIR LIQUIDE ITALIA SERVICE S.R.L. AREA RAVENNA RESPONSABILITÀ MANUTENZIONI E INSTALLAZIONI <small>(Reg. Tribunale L09)</small>	PER IL CLIENTE
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# RAPPORTO DI INTERVENTO TECNICO

AIR LIQUIDE ITALIA SERVICE S.p.A. - SEDE LEGALE E AMMINISTRATIVA: 20140 158 4110 - VIA CAPELLANNO, 49  
 41100 MODENA - TEL. 059 2185111 - FAX 059 2185112 - E-MAIL: AIR.LIQUIDE@ENEA.IT  
 CAPITALE SOCIALE € 100.000.000,00 - C.F. 03383340158 - P.I. 03383340158 - C.C. 2284  
 CODICE FISCALE E PARTITA IVA 03383340158 - R.E.A. C.C.I.A.A. EMILIA/RM 203375 - www.airliquide.it

**AIR LIQUIDE ITALIA SERVICE S.p.A.**  
 REGIONE ADRIATICA - SITO DI MODENA  
 Via N. Biondo, 485/A  
 41100 MODENA

RAPPORTO N. _____	DATA <b>16/03/13</b>	TECNICO SIG. <b>FORZANZELL</b>
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ESEGUITO PRESSO: **ENEA CARONANO ICE BOSSIMIRE**

INDIRIZZO: \_\_\_\_\_

PERSONA CONTATTATA: **SG GRANICH**

TIPO DI INTERVENTO:  ORDINARIO  STRAORDINARIO

TIPO DI IMPIANTO O APPARECCHIO: \_\_\_\_\_

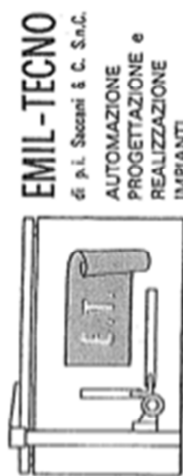
MATRICOLA N: \_\_\_\_\_ DATA D'INSTALLAZIONE: \_\_\_\_\_

MOTIVO DELL'INTERVENTO: **INSTALLAZIONE LINEE GAS N°102/1020004/ACCENSIONE**

MATERIALI UTILIZZATI - DESCRIZIONE
<b>Epletto per installazione centralizzatore gas sul regolatore prove di funzionalità e tenuta.</b>
<b>Si inserisce sulle piste junctionate e non pannello mobile centrale</b>

ENTRATO ORE: <b>10.00</b>	<b>FIRMA DEL TECNICO</b>  <b>AIR LIQUIDE ITALIA SERVICE S.p.A.</b> REGIONE ADRIATICA - SITO DI MODENA Via N. Biondo, 485/A 41100 MODENA	TIMBRO E FIRMA DELLA CITTA
USCITO ORE: <b>13.00</b>		
VIAGGIO ORE: <b>2h</b>		
PERCORSO km: _____	SEGUIRÀ REGOLARE FATTURA INTESTATA A: _____ (la fatturazione comprenderà anche i tempi di viaggio, nonché le spese relative)	
VARIE		

- GAS TECNICI, PURI, PURISSIMI, MEDICALI
- IMPIANTI, APPARECCHI E CONTENITORI PER CRIOGENIA E CRIOBIOLOGIA
- IMPIANTI PER TRASPORTO REFRIGERATI
- TUNNELS DI SURGELAZIONE
- IMPIANTI CENTRALI DI DISTRIBUZIONE GAS
- APPARECCHI MEDICALI
- IMPIANTI, APPARECCHI AUTOMATICI E SEMIAUTOMATICI, MATERIALI, PRODOTTI E ACCESSORI PER OGNI SISTEMA DI SALDATURA E TAGLIO
- PROCEDIMENTI TIG, MIG, ARCOSOMMERSO, TAGLIO E SALDATURA PLASMA
- IMPIANTI PER IL FRAZIONAMENTO DEI GAS DELL'ARIA
- TANKS MOBILI E FISSI PER LO STOCCAGGIO DI GAS CRIOGENICI LIQUEFATTI

**EMIL-TECNO**

di P.L. Sacconi &amp; C. S.n.c.

AUTOMAZIONE

PROGETTAZIONE e

REALIZZAZIONE

IMPIANTI

41100 MODENA - VIA EMILIA OVEST, 900 - TEL. (059) 33.52.71

FAX (059) 82.72.50

Magazzini: Via Emilia Ovest, 900/F - Modena

Codice Fiscale e Partita IVA 00036560299

## DICHIARAZIONE CE DI CONFORMITA'

Il sottoscritto, rappresentante della ditta EMIL-TECNO Snc, Via Emilia Ovest, 930-41123 MODENA

**DICHIARA CHE IL QUADRO ELETTRICO – IMPIANTO A BORDOMACCHINA**

**Denominato:** Quadro elettrico per comando valvole gas tecnici.

**Matricola:** 009/13

**Anno di costruzione:** 2013

E' costruito per essere incorporato in una macchina ed è conforme con quanto previsto dalle seguenti direttive comunitarie:

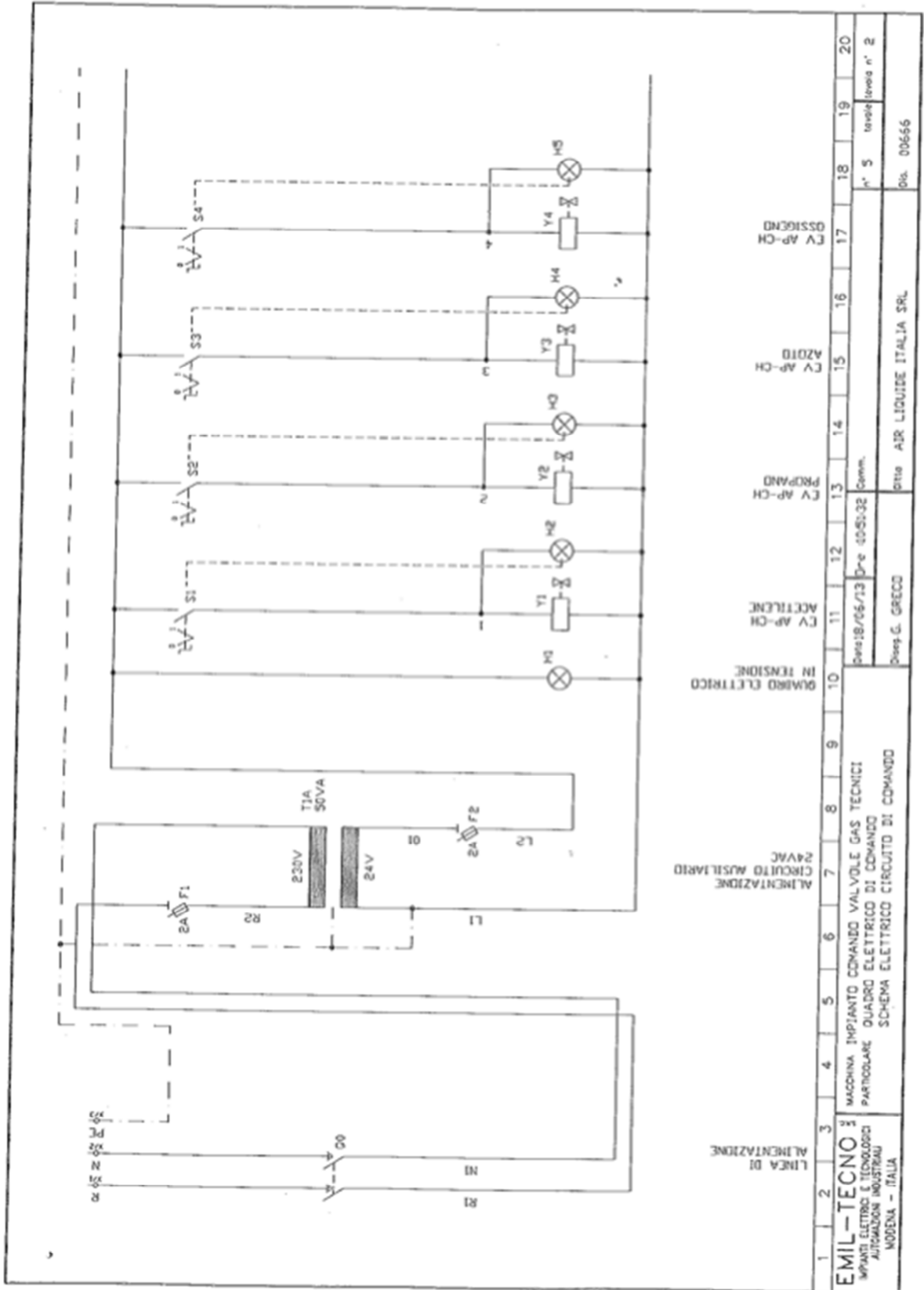
73/23/CEE – 93/68/CEE  
89/336/CEE – 92/31/CEE

Direttiva bassa tensione  
Direttiva compatibilità elettromagnetica

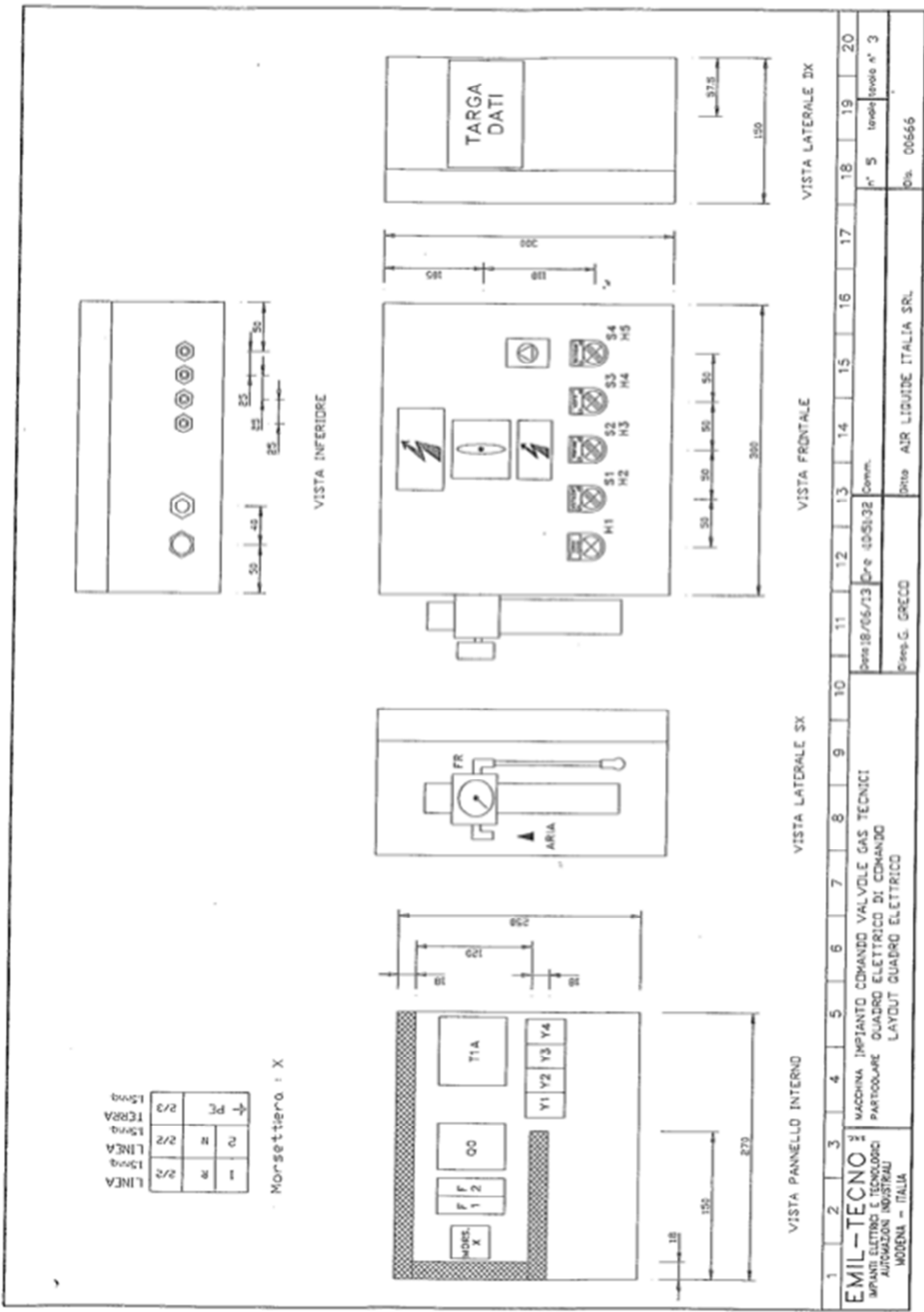
e che sono state applicate tutte le norme sottoindicate.

CEI EN 60439-1 (CEI 17-13/1)  
CEI EN 60204-1 (CEI 44-5)



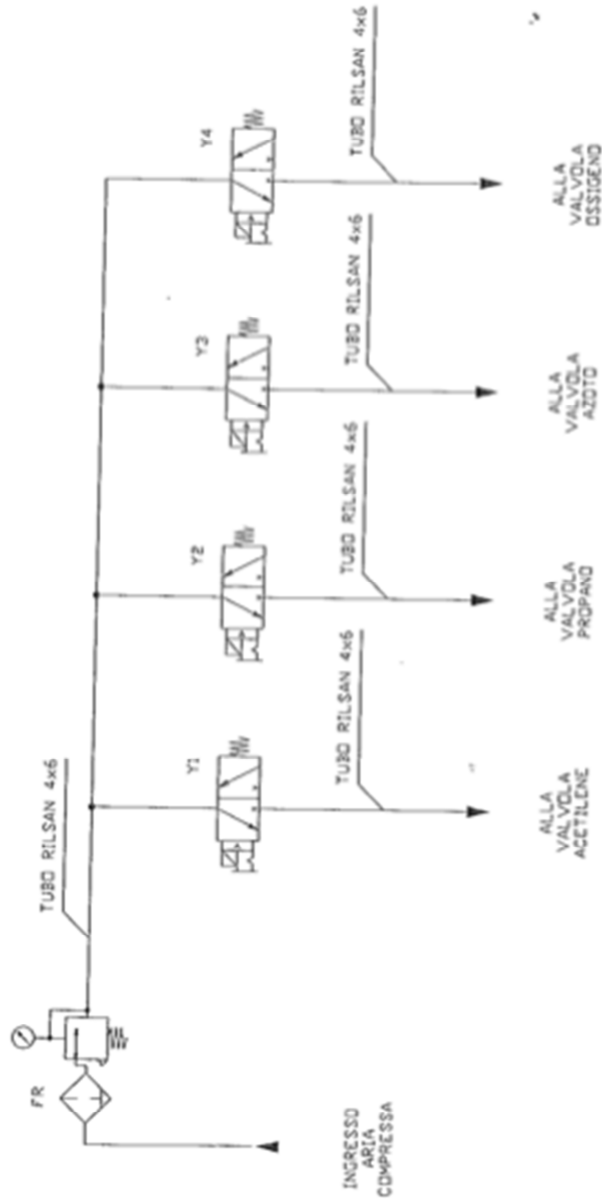


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<b>EMIL-TECNO</b> IMPALTI ELETTRICI E TECNOLOGICI AUTOMAZIONI INDUSTRIALI MODENA - ITALIA			MACCHINA IMPIANTO COMANDO VALVOLE GAS TECNICI PARTICOLARE QUADRO ELETTRICO DI COMANDO SCHEMA ELETTRICO CIRCUITO DI COMANDO																
Disegnato: 18/06/13 Disegnato: 00-01-32 Comm.											n° 5 livello/levata n° 2		Disegnato: AIR LIQUIDE ITALIA SRL Oss. 00666						



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AUTOMAZIONI INDUSTRIALI			LAYOUT QUADRO ELETTRICO																
MODENA - ITALIA			Ditta AIR LIQUIDE ITALIA SRL																
			Disegn. G. GRECO																
			Data 18/06/13 Ore 10:51:32 Conv.																
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			torace levata n° 4																



STIGLA	DESCRIZIONE	MARCA E TIPO	POS.
F1	FUSIBILE PROTEZIONE TRASFORMATORE TIA	SIEMENS 3N47013	2/6
F2	FUSIBILE PROTEZIONE CIRCUITO AUSIL. BAVAC	SIEMENS 3N47013	2/8
FR	FILTRO RIDUTTORE ARIA COMPRESSA	PNEUMAX 170044BCP+M4012	4/3
H1	LAMPADA SPIA QUADRO IN TENSIONE	SCHNEIDER ZB4BV21-ZB4BV013	2/10
H2	LAMPADA SPIA EV Y1 APERTA	SCHNEIDER ZB4BV21	2/12
H3	LAMPADA SPIA EV Y2 APERTA	SCHNEIDER ZB4BV21	2/14
H4	LAMPADA SPIA EV Y3 APERTA	SCHNEIDER ZB4BV21	2/16
H5	LAMPADA SPIA EV Y4 APERTA	SCHNEIDER ZB4BV21	2/18
IO	INTERRUTTORE GENERALE	SCHNEIDER V02-KCF1P2	2/2
S1	SELETORE AP-CH ELETTROVALVOLA Y1	SCHNEIDER ZB4BK1213-ZBC101	2/11
S2	SELETORE AP-CH ELETTROVALVOLA Y2	SCHNEIDER ZB4BK1213-ZBC101	2/13
S3	SELETORE AP-CH ELETTROVALVOLA Y3	SCHNEIDER ZB4BK1213-ZBC101	2/15
S4	SELETORE AP-CH ELETTROVALVOLA Y4	SCHNEIDER ZB4BK1213-ZBC101	2/17
TIA	TRASFORMATORE DI TENSIONE MONOFASE	CUOGGI Tmk 230/24 SOVA	2/7
Y1	ELETTROV. AP-CH VALVOLA ACETILENE	PNEUMAX 305MI+NB17	2/11
Y2	ELETTROV. AP-CH VALVOLA PROPANO	PNEUMAX 305MI+NB17	2/13
Y3	ELETTROV. AP-CH VALVOLA AZOTO	PNEUMAX 305MI+NB17	2/15
Y4	ELETTROV. AP-CH VALVOLA OSSIGENO	PNEUMAX 305MI+NB17	2/17
	CARPENTERIA QUADRO ELETTRICO:	ZANARDO D03/41	
	MATERIALE:	LAMIERA INOX AISI304	
	DIMENSIONI:	300x500x150mm	
	GRADO DI PROTEZIONE:	IP65	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
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			Dis. 00666																
			Data 20/06/13 ore 15:31:05 form.																
			n° 5 tavola tavola n° 5																

## OUTLOOK

The experimental hall has been completed, the DS machine will be installed during the month of October.

The system for DS will be constituted by an automated system:

- The coating gun itself, consisting of the torch and the propeller-target tanks
- A robotic arm for the coating performance
- A static substrate tripod, with the possibility to implement a second robotic arm
- A standard acoustic insulated chamber for the coating performance, with dedicated control room
- An external safety gas supply system, [*refs 1, 2, 3, 4*].

Consisting of a “thermal spray” system, the DS is able to coat the external part of tubings or other simple geometry components, thus being suitable for fuel claddings mock ups.

After a short training by STPC personnel, the very first experimental campaign will, as a first step, target the following coating possibilities:

- Alumina ( $\text{Al}_2\text{O}_3$ ) coatings
- Ta coatings

Alumina, as well as Tantalum, are two of the most effective protective coatings against Pb, and with the DS the alumina compound can be sprayed directly as oxide.

The qualification of the DS coating method and surface engineering needs for the nuclear systems, by means of Pb corrosion tests and mechanical tests, with the goal of improving their safety and reliability, constitutes the starting point for the next PAR experiments.

## REFERENCES.

- [1]. Air Liquide scheda di dati di sicurezza AL.5.21
- [2]. Air Liquide scheda di dati di sicurezza AL.001
- [3]. Air Liquide scheda di dati di sicurezza AL.089A
- [4]. Air Liquide scheda di dati di sicurezza AL.097A