

**ROYAL SCIENTIFIC SOCIETY**  
**MECHANICAL DESIGN AND TECHNOLOGY CENTER**

Corrosion Engineering Division  
P.O. Box 1438 Jubaiha 11941, Amman - Jordan, Telex:21276  
Fax : (962)6-5344806, Phone : (962)6-5344701-9

TEST REPORT NO 351/06/5

Designation No.: 3/05/1819

Our Ref. & Date: (3)148/55/1/22467 Date: 09/2006  
Method of Sampling:  
Date of Test:

This study is based on verifying the effect of using HYDROFLOW Technology given in fig.(1), in reducing scaling and corrosion rate in JORDAN STEEL FACTORY (JSF). Seven random positions were selected in JSF cooling water piping network as shown in fig.( 2) to install ( 14 ) corrosion and scale coupons as shown in figs.( 3-10) for one year ( 4/1/2006 to 4/1/2007) .Seven Carbon Steel coupons ( 2 x 4 cm.) as well as bolts and nuts were fabricated from the same material of JSF piping network at MDTC/RSS mechanical workshop in order to use them as corrosion coupons (CC) to be connected in the selected positions given in fig.(2). Seven Scale coupons (SC) ,( 2 x 4 cm.) of Super Stainless Steel Alloy ( NAS 254N) as well as ( S 64 , 304) supplied by NIPPON YAKIN KOGYO CO.,LTD/JAPAN were fabricated at MDTC/RSS mechanical workshop in order to use them as scale coupons to be connected in the selected positions given in fig.(2) using plastic bolts and nuts to eliminate the GALVANIC action that might occur between the material of the scale coupons and the material of the pipe.



Fig.(1) Hydroflow technology ( photo to the left) connected to one of the pipes in a selected location of JORDAN STEEL FACTORY ( photo to the right).

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*Masaomi Tsuda*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*

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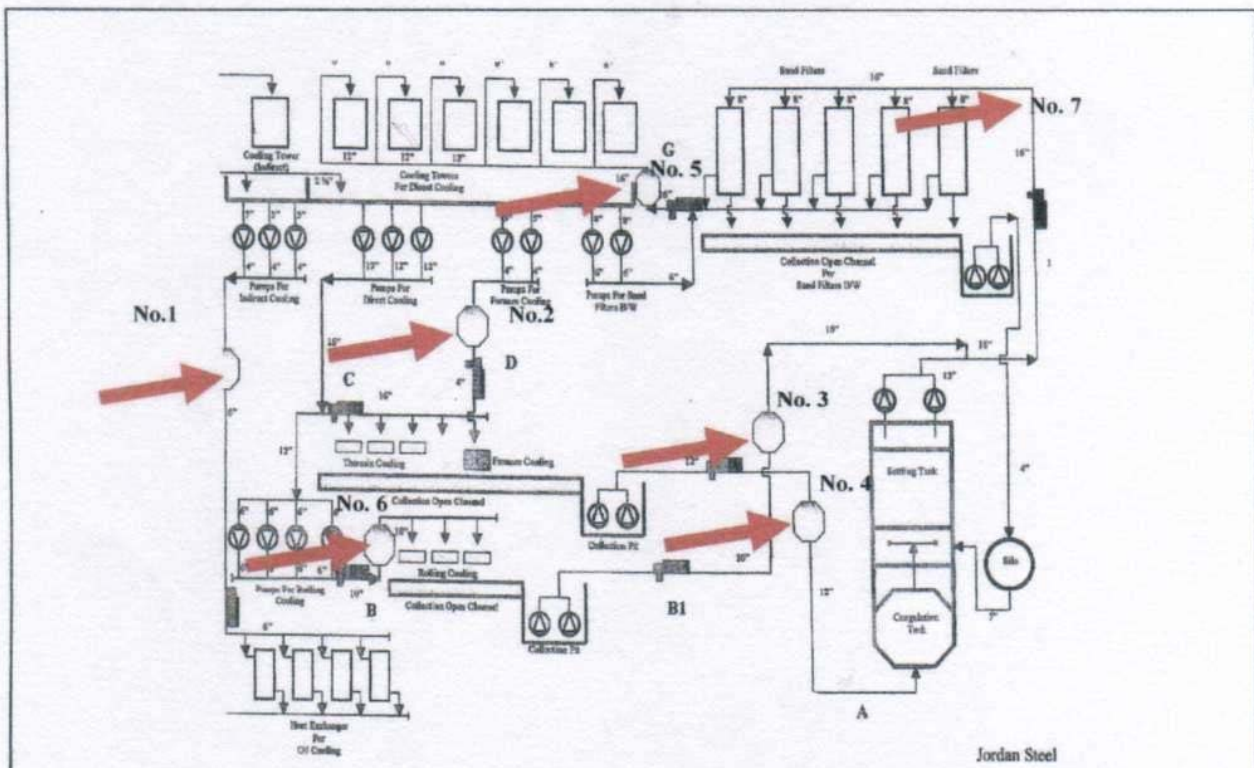


Fig.(2) Arrows refer to the positions of corrosion and scale coupons in JSF cooling water piping network.

Consultant: Dr. Farqad F.M. Saeed *F. F. Saeed*  
 Consultant: Dr. M. Tsuda  
*Masaomi Tsuda*

Head of Division: Dr. Azzam A. Odeh  
*Dr. A. Odeh*



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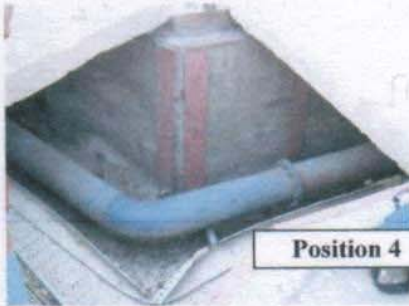


Fig.(3) Selected positions given in fig.(2) in JSF.

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*F. F. Saeed*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*

*Masaomi Tsuda*



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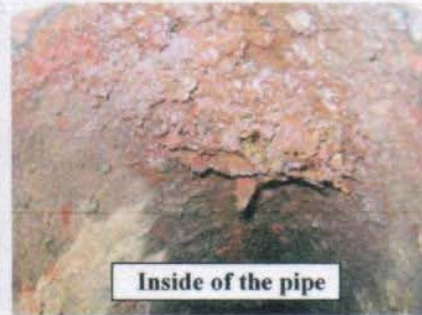
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Inside of the pipe



CC No5(carbon steel)

SC No11(NAS64)



Fig.(4):Shows the installation of the Corrosion Coupon and Scale Coupon in Position No. 1(6 inch)

Consultant:Dr.Farqad F.M.Saeed  
Consultant:Dr.M.Tsuda

*Masaomi Tsuda*

*F. Saeed*

Head of Division: Dr.Azzam A.Odeh

*Dr. A. Odeh*



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Inside of the pipe

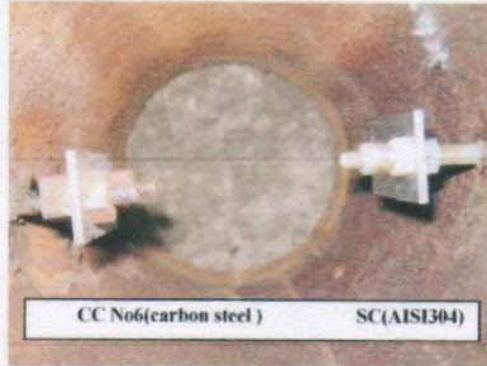


Fig.(5): Shows the installation of the Corrosion Coupon and Scale Coupon in Position No. 2(4 inch)

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*F.M. Saeed*

*Masaomi Tsuda*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*

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Fig.(6): Shows the installation of the Corrosion Coupon and Scale Coupon in Position No.3(10 inch)

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*Masaomi Tsuda*

*F. Saeed*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*



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Inside of the pipe



CC No2 (carbon steel)



SC No8 (NAS254N)

Fig.(7): Shows the installation of the Corrosion Coupon and Scale Coupon in Position No.4 (12inch)

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*F. M. Saeed*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*

*Masaomi Tsuda*



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Inside of the pipe



CC No 1(carbon steel)



SC No 7( NAS254N)

Fig.(8): Shows the installation of the Corrosion Coupon and Scale Coupon in Position No.5 (16 inch)

Consultant:Dr.Farqad F.M.Saeed  
Consultant:Dr.M.Tsuda

*Masaomi Tsuda*

*F. F. Saeed*

Head of Division: Dr. Azam A. Odeh



*Dr. A. Odeh*

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CC No 4 (carbon steel)



SC No 10 (NAS 254N)

Fig.(9): Shows the installation of the Corrosion Coupon and Scale Coupon in Position No.6(10 inch)

Consultant:Dr.Farqad F.M.Saeed  
Consultant:Dr.M.Tsuda

*F. Saeed*

*Masaomi Tsuda*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*



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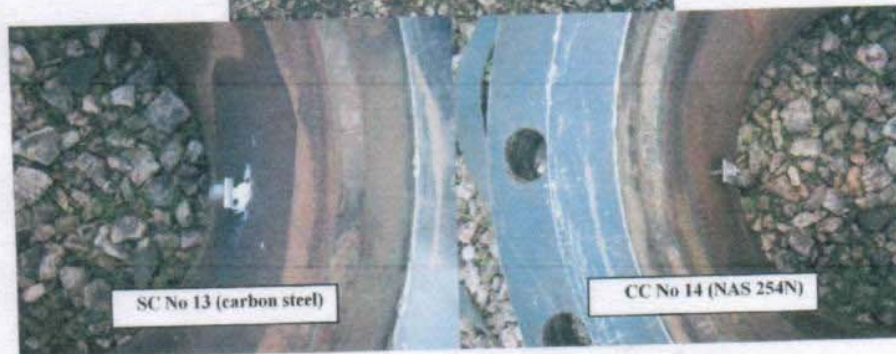


Fig.(10): Shows the installation of the Corrosion Coupon and Scale Coupon in Position No.7(16 inch)

Consultant:Dr.Farqad F.M.Saeed  
Consultant:Dr.M.Tsuda

*Masaomi Tsuda*

*Dr. Saeed*

Head of Division: Dr.Azzam A.Odeh

*Dr. A. odeh*



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Chemical analysis of the products existing on the surface of the piping network revealed high quantities ( 60-70 %) of  $FeO$ ,  $Fe(OH)_2$  and  $Fe_3O_4$  combined with greasy material before installing the corrosion and scale coupons to the piping network.

Chemical analysis of the Well water, Indirect cooling system and Direct cooling system revealed quantities of SULFATE REDUCING BACTERIA (SRB) before installing the corrosion and scale coupons to the piping network.

Randomly selected position (position no.3) was opened after 3 months (7/4/2006) in order to conduct visual inspection without removing the coupons from its location as shown in fig.(11). Visual inspection revealed traces of brownish products on the surface of the corrosion coupon as well as the surface of the pipe.



Fig.(11): Visual inspection of the Corrosion coupon ( to the left) and scale coupon (to the right)

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*Masaomi Tsuda*

*F. Saeed*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*



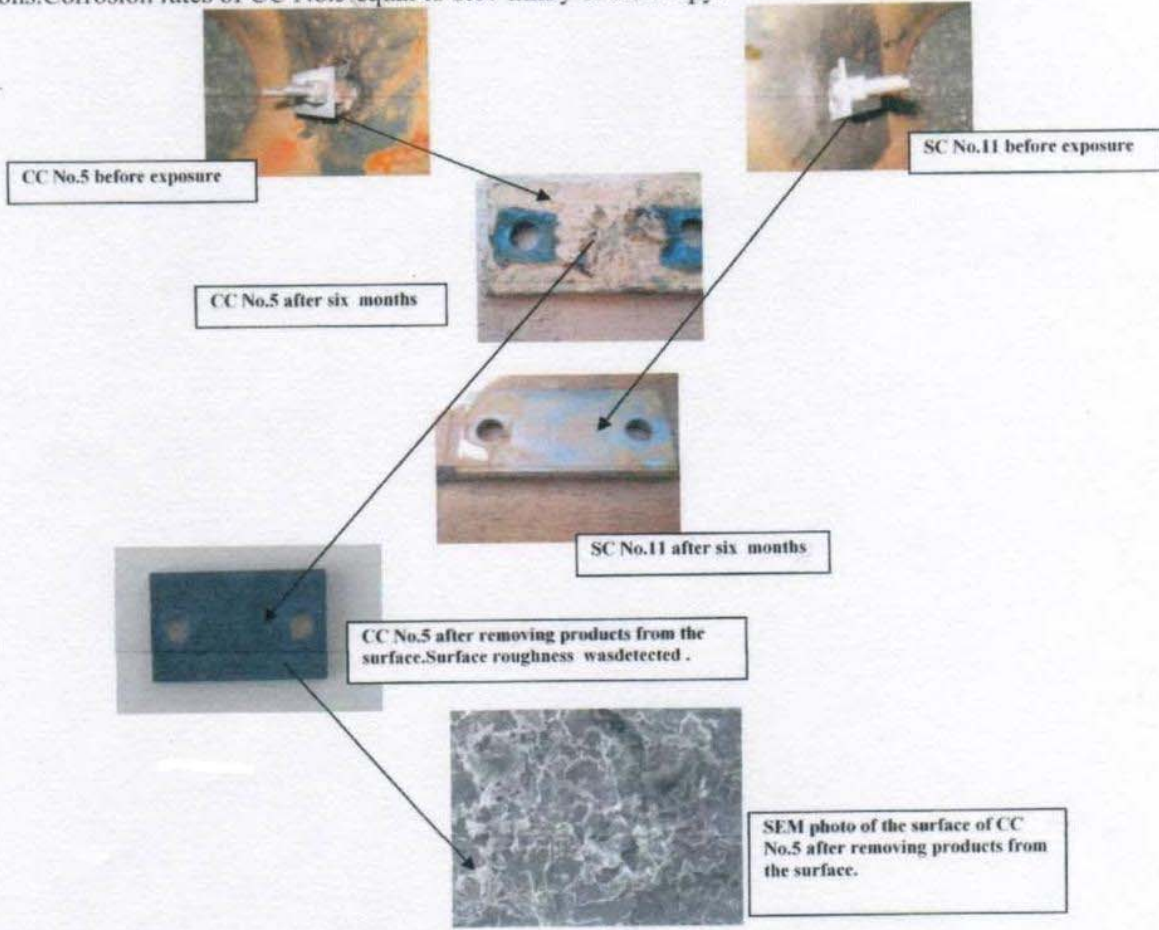
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Corrosion and Scale coupons were removed from positions no.s (1 and 3) after six month of exposure (1/7/2006). The surface of the corrosion and scale coupons of position no. (1) were covered with brownish colored material . Chemical analysis of the material collected from surface of the scale coupon revealed (49-55%) iron oxides , (1-7 %) CaCO<sub>3</sub> ,greasy material and traces of sulfate, chloride ,magnesium ions. Corrosion rates of CC No.5 equal to 0.09 mm/y or 3.54 mpy .



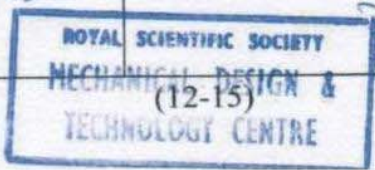
Consultant: Dr. Farqad F.M. Saeed  
 Consultant: Dr. M. Tsuda

*F. Saeed*

Head of Division: Dr. Azzam A. Odeh

*Dr. A. Odeh*

*Masaomi Tsuda*



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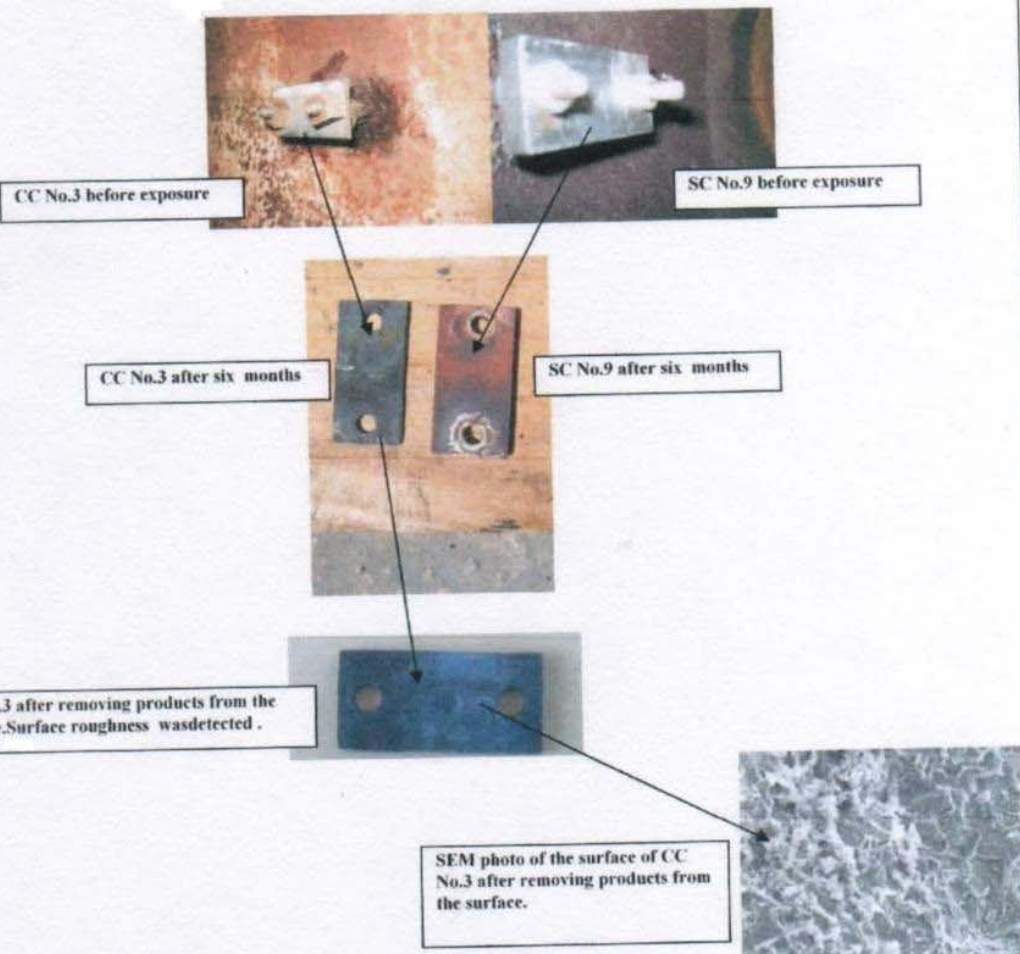
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The surface of the corrosion and scale coupons of position no. (3) were covered with brownish colored material . Chemical analysis of the material collected from surface of the scale coupon revealed (45%) iron oxides , (45 %)  $\text{CaCO}_3$  ,greasy material and traces of sulfate, chloride ,magnesium ions. Corrosion rates of CC No.3 equal to 0.4807 mm/y or 18.925 mpy.



Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

*F. Saeed*

*Masami Tsuda*

Head of Division: Dr. Azzam A. Odeh

*A. Odeh*

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Corrosion and Scale coupons were removed from position no.(6) after seven month of exposure (1/8/2006).The surface of the corrosion and scale coupons of position (6) were covered with brownish colored material .Chemical analysis of the material collected from surface of the scale coupon revealed (41-52% ) iron oxides , (20 %)  $\text{CaCO}_3$  ,greasy material and traces of sulfate, chloride ,magnesium ions.Corrosion rates of CC No.4 equal to 0.1337mm/y or 5.26 mpy.



CC No.4 before exposure



SC No.10 before exposure

CC No.4 after removing products from the surface.Surface roughness was detected .Seven months of exposure



SC No.10 after seven months

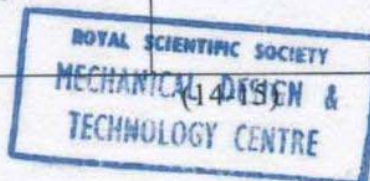
SEM photo of the surface of CC No.4 after removing products from the surface.



Consultant:Dr.Farqad F.M.Saeed  
Consultant:Dr.M.Tsuda

Head of Division: Dr.Azzam A.Odeh

*Masaomi Tsuda*



*Dr. A. Odeh*

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**EVALUATION:**

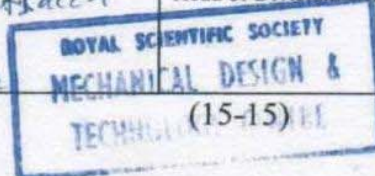
Corrosion phenomena existed due to the presence of the following **Three** factors : Iron oxides ,scaling and SULFATE REDUCING BACTERIA (SRB) .Iron oxide precipitations formed concentration cells which caused the corrosion phenomena to occur in addition to the existence of SRB . SRB is an anaerobic bacteria which reduces (SO<sub>3</sub>) to sulfide and forming H<sub>2</sub>S gas under the scaling film (H<sub>2</sub>S gas is considered a very aggressive corrosive media).

Corrosion rate results of CC No.s ( 3 & 4) located in direct cooling system showed higher values than CC No.( 5) located in indirect cooling system due to the presence of higher percentages of scaling in addition to iron oxide precipitations and oxygen content. Corrosion rate results of CC 4 No.4 (exposure time equal to SEVEN months)is ( 5.26 mpy) which is less than the corrosion rate of CC No.3 (exposure time equal to SIX months) (18.925 mpy), which means that corrosion rate results are improving with time due to the performance of HYDROFLOW TECHNOLOGY. In addition to the above iron oxide percentages on the surface became lower with time because chemical analysis of the products collected from the internal surface of the pipes on 4/1/2006 showed iron oxide percentages equal to (60-70 %) while the chemical analysis of the products collected from the internal surface of the pipes on 1/8/2006 showed iron oxide percentages equal to (49 %) , which means that iron oxide percentages are becoming lower with time due to the performance of HYDROFLOW TECHNOLOGY which will be reflected positively on reducing the rate of corrosion .On the other hand scaling percentages of SC No.10 ( 20 % of total products on the surface of the coupon) which is less than the scaling percentages of SC No.9 ( 45 % of total products on the surface of the coupon) although the exposure time of SC No.10 is SEVEN months while SC No.9 is SIX months, which means that scaling percentages are becoming lower with time due to the performance of HYDROFLOW TECHNOLOGY which will also be reflected positively on reducing the rate of corrosion.

Consultant: Dr. Farqad F.M. Saeed  
Consultant: Dr. M. Tsuda

Head of Division: Dr. Azzam A. Odeh

*Masaomi Tsuda*



*Dr. A. Odeh*