



INSTRUMENTATION TUBING FOR DEMANDING ENVIRONMENTS



OIL + GAS + TRANSPORTATION + MARINE + DEFENCE + MEDICAL



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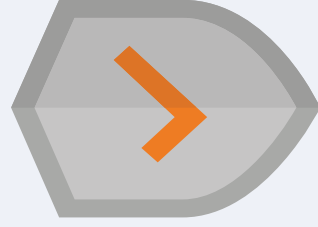
TUNGUM TUBING

A proven performance



\$7,000,000
OFFSHORE ASSET
SAVING
USING TUNGUM TUBE

NO RECORDED
FAILURES
OF TUNGUM TUBING



TUNGUM TUBE
HAS BEEN USED IN
SAFETY CRITICAL
APPLICATIONS
FOR OVER

80
YEARS



FIT
AND
FORGET

01



: PROFILE

What is Tungum Alloy?

Product Summary

Tungum Tubing Versus...

Project Based Cost Comparison

WHAT IS TUNGUM ALLOY?

What makes it such a versatile material?

Tungum Alloy Tubing C69100 combines an unusually high strength to weight ratio, with ductility, excellent corrosion resistance, and first class fatigue properties. Highly resistant to sea water and its atmosphere, Tungum resists both pitting and crevice corrosion to offer outstanding serviceability, even at intermittent duty in the highly corrosive 'splash zone' offshore.

Non-magnetic and non-sparking properties make Tungum invaluable in piping high pressure gases, particularly oxygen, where its thermal conductivity/diffusivity characteristics virtually eliminate the potential dangers present when other materials are used.

When used in high pressure hydraulic or pneumatic circuits, these features together with inherent 'clean bore' characteristics combine in giving an easily constructed, high integrity system.

This requires a minimum of purging and no external protective treatment.

Tungum Alloy is ideal in cryogenic applications, suitable for chemical engineering and low temperature processes. Its corrosion resistance enables its use in conveying fluids and gases containing corrosive elements.

+

+ TUNGUM ALLOY TUBING C69100 HAS BEEN USED FOR HIGH QUALITY SAFETY CRITICAL APPLICATIONS FOR OVER 30 YEARS

+ EXCELLENT LIFETIME COST COMPARED TO OTHER TUBING OPTIONS. TYPICALLY 15% CHEAPER THAN G60 AND SUPER DUPLEX TUBING

+ THERE ARE NO RECORDED FAILURES OF TUNGUM TUBING WHEN CORRECTLY USED AND INSTALLED

+ WE USE THE EXPRESSION 'FIT AND FORGET' DUE TO ITS LONG LIFE AND EXCELLENT CORROSION RESISTANCE



**TROUBLE AND MAINTENANCE FREE
PERFORMANCE WHERE IT REALLY MATTERS**

+

Tungum Tubing is found around the world contributing to the success and longevity of applications in a wide cross section of industries, including:

- + HIGH PRESSURE GAS
- + OFFSHORE OIL
- + AEROSPACE
- + RAIL AND TRANSPORT
- + DEFENCE
- + CIVIL ENGINEERING
- + PHARMACEUTICAL
- + MEDICAL
- + NUCLEAR



COMPARED TO SUPER DUPLEX MATERIALS:

SIGNIFICANTLY CHEAPER AND EASIER TO INSTALL THAN SUPER DUPLEX MATERIALS

TUNGUM TUBING:

Product summary

Tungum Tubing has been used in the field for over 80 years in demanding, safety critical applications. There are no recorded failures of Tungum when correctly used and installed. This is why we use the expression: 'fit and forget' due to its long life and excellent corrosion resistance.

Features and benefits of Tungum:

- + Excellent lifetime cost compared to other tubing options. Typically 15% cheaper than 6Mo and Super Duplex tubing.
- + No recorded failures of Tungum Tubing when correctly used and installed in over 30 years of application experiences.
- + Compatible and approved with all industry recognised tube fittings.
- + Quicker installation times – can be as little as 75% of the time compared to 6Mo or Super Duplex.
- + Reduced system down times due to its longer life.
- + Material of choice for Oxygen and hyperbaric systems.
- + High resistance to fatigue and shock for applications where there is excessive vibration.
- + Over 30 years of experience of real time Oil & Gas applications.
- + Highly resistant to sea water and its atmosphere. It resists both pitting and crevice corrosion to offer outstanding performance, especially in highly corrosive 'splash zones'.
- + Non-magnetic and non-sparking properties make it ideal for high pressure gas applications.
- + Cryogenic material, suitable for chemical engineering and low temperature processes.
- + Wide range of sizes in both imperial and metric.
- + World wide distributor network.

COMPARED TO 316 STAINLESS STEEL:

**+ 4 - 6 TIMES THE WORKING LIFE
+ DOES NOT SUFFER THE SAME PITTING AND CREVICE CORROSION ISSUES
+ UP TO 1/3 LESS TIME TO INSTALL**

TUNGUM TUBING VERSUS...

Super duplex and Austenitic Stainless Steels

Tungum Alloy Tubing C69100 combines an unusually high strength to weight ratio, with ductility, excellent corrosion resistance, and first class fatigue properties. Highly resistant to sea water and its atmosphere, Tungum resists both pitting and crevice corrosion to offer outstanding serviceability, even at intermittent duty in the highly corrosive 'splash zone' offshore.

Competitive project costings:

In comparison to material grades such as Alloy 6Mo, 400, 625, 2507 and C276, Tungum Tubing has a highly competitive base material cost. In many cases Tungum has a better lifetime operational cost. See *Lifetime Capital Cost Comparison Chart on the next page.*

Tungum Tubing is used in combination with many types of fittings. In most cases 316 Stainless Steel Twin Ferrule Compression fittings are used. These provide major savings against using other tube and fittings combinations such as 6Mo or 2507 Alloys.

Note: there is no preferential corrosion between Tungum and Stainless Steel as both materials are similar on the galvanic scale.

Excellent corrosion resistance

Independent testing shown in NACE 10305 paper (see Corrosion Resistance Testing in Technical Data Section) concludes that Tungum has the best localised corrosion resistance relative to other Alloys.

Note that the standard corrosion tests for Stainless Steel are not applicable to Tungum Tubing as it is a copper based alloy – this includes PREN, ASTM G48 and CPT testing.

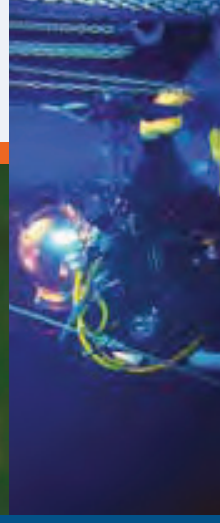
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LIFETIME OPERATING COST IMPACT

In recent years standard 316 and 317L Stainless Steel tubing has been replaced in many applications. Where long-term operating costs have become more important than initial project build cost, Tungum Tubing has been specified on many projects for this reason. For example, the price of instrumentation tubing for a standard installation using stainless steel compared with using Tungum Tubing is approximately one third. However, by using stainless steel you can expect anything from 5-10 refits over the life of an installation.

When replacing material other costs can include:

- + REMOVAL / REINSTALLATION OF TUBING
- + DOWNTIME LOSS OF PRODUCTION
- + DISPOSAL OF OLD TUBE & FITTINGS



INSTALLATION TIME – 30% QUICKER THAN SUPER DUPLEX AND 6MO AS TUNGUM IS EASIER TO BEND AND INSTALL

PROJECT BASED TUBE AND FITTING COST COMPARISON

Reason: Concerns about differences in total material tube/fitting combination costs

Notes: prices shown are in \$ USD and are based on the quantity of Tungum Tubing supplied on a project during 2015

TUBE SIZE AND WALL THICKNESS	QUANTITY IN FT.	TUNGUM TUBING AND 316 FITTINGS	TUNGUM TUBING AND TRIPLELOK BRASS FITTINGS	316 TUBE AND FITTINGS	6MO TUBE AND FITTINGS	2507 TUBE AND FITTINGS	625 TUBE AND FITTINGS	C276 TUBE AND FITTINGS
.250"od x .065"	40	\$353	\$328	\$123	\$538	\$940	\$1,008	\$931
.500"od x .083"	147,592	\$1,512,365	\$1,331,233	\$1,202,422	\$2,896,919	\$4,677,597	\$9,341,364	\$9,102,331
.750"od x .109"	930	\$29,266	\$26,752	\$11,977	\$43,892	\$69,613	\$98,617	\$132,597
1.00"od x .134"	49,282	\$1,328,798	\$1,055,307	\$1,110,479	\$2,698,912	\$5,076,157	\$6,882,351	\$11,141,531
TOTAL		\$2,870,782	\$2,413,620	\$2,325,001	\$5,640,261	\$9,824,307	\$16,323,340	\$20,377,390
INITIAL SAVINGS USING TUNGUM TUBING AND 316 FITTINGS				-\$545,782	\$2,769,479	\$6,953,524	\$13,452,558	\$17,506,608
PREDICTED TIME TO FAILURE		30 YEARS PLUS	30 YEARS PLUS	4 YEARS	20 YEARS	20 YEARS	30 YEARS	30 YEARS

Contact us to find out how much you could save.



TUNGUM IS A VERY COST EFFECTIVE PRODUCT:

THE FACT THAT IT DOESN'T GIVE US ANY ISSUES, WE HAVE NO RECORDED FAILURES AND IT DOES EXACTLY WHAT IT WAS SPECIFIED FOR IS A MAJOR SUCCESS IN KEEPING US WORKING WITHOUT ANY DOWNTIME.

IT ALSO LASTS WHERE OTHER PRODUCTS HAVE BEEN AN ISSUE WITH REGARD TO CORROSION DAMAGE IN THE HARSH SALT WATER ENVIRONMENT.



Bruce Collie, Sr. Tech. Support Diving Equipment Subsea 7.



CASE STUDIES : PAGE 26

02



: KEY BENEFITS

Features and Benefits

FEATURES AND BENEFITS

A summary of the material's benefits

- + Excellent lifetime cost compared to other tubing options. Typically 15% cheaper than 6Mo and Super Duplex tubing.
- + No recorded failures of Tungum Tubing when correctly used and installed in over 30 years of application experiences.
- + Compatible and approved with all industry recognised tube fittings.
- + Quicker installation times – can be a third less of the time compared to 6Mo or Super Duplex.
- + Reduced system down times due to its longer life.
- + Material of choice for Oxygen and Hyperbaric systems.
- + High resistance to fatigue and shock for applications where there is excessive vibration.
- + Over 30 years of experience of real time Oil & Gas applications.
- + Highly resistant to sea water and its atmosphere. It resists both pitting and crevice corrosion to offer outstanding performance, especially in highly corrosive 'splash zones'.
- + Non-magnetic and non-sparking properties make it ideal for high pressure gas applications.
- + Cryogenic material, suitable for chemical engineering and low temperature processes.
- + Wide range of sizes in both imperial and metric.
- + Worldwide distributor network.



Highly resistant to sea water



High resistance to fatigue and shock



Compatible with all industry recognised tube fittings.



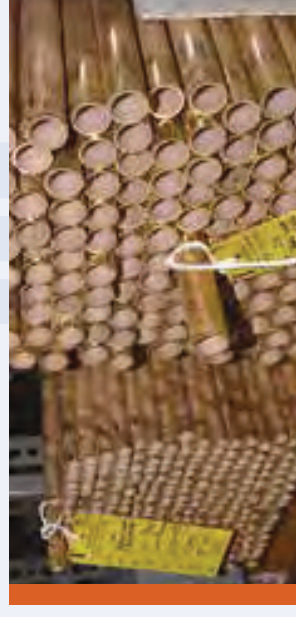
Quicker installation times



Worldwide distributor network



Excellent lifetime cost



OVER 30 YEARS OF EXPERIENCE OF REAL TIME OIL & GAS APPLICATIONS

03



: APPLICATIONS

Typical Applications

Oil and Gas

Dive Systems

Naval and Commercial Marine

Medical

Defence

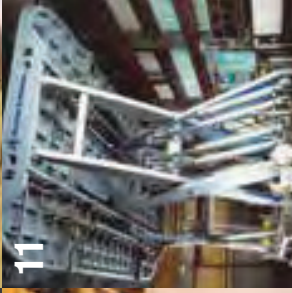
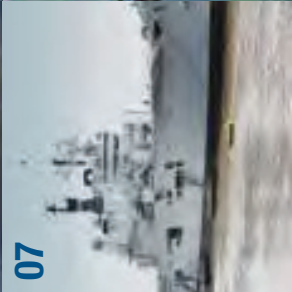
Transportation

TYPICAL APPLICATIONS:

For Tungum Alloy Tubing C69100

The pictures shown here highlight the wide spectrum of applications in which Tungum Alloy Tubing is employed. The high strength to weight ratio, ductility, excellent corrosion resistance, and first class fatigue properties enables Tungum Alloy Tubing to offer benefits to a wide and diverse spectrum of applications and industry sectors.

01. BP Mad Dog Platform
02. Tolsa Paladin – Dive Support Vessel
03. Tower Bridge
04. Bombardier, Gairtrain
05. Warrior Armoured Personnel Carrier
06. Millwall Cut Bridge
07. British Naval Vessel – HMS Chiddingfold
08. Black Magic – PC9M Trainer Plane
09. SAK 40 Trinity Bofors Gun
10. Pipeline Inspection Equipment
11. Aircraft Carrier Scissor Lift



We would like to thank all the companies who have provided pictures for this Product Manual.

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TYPICAL APPLICATIONS FOR TUNGUM ALLOY TUBING C69100 INCLUDE:

- + HYDRAULIC SYSTEMS
- + PNEUMATIC SYSTEMS
- + OXYGEN SYSTEMS
- + DIESEL / FUEL LINES
- + SEA WATER SYSTEMS
- + PRESSURE SENSING SYSTEMS
- + TEMPERATURE SENSING ELEMENT LOOPS
- + PORTABLE WATER SYSTEMS
- + GREY & BLACK WATER SYSTEMS
- + CHEMICAL INJECTION SYSTEMS – CAUTION, SOLUTION COMPATIBILITY
- + CONDUIT TUBING – EMERGENCY SHUTDOWN SYSTEMS
- + BRAKE PIPES

IMPORTANT NOTE – AVOID APPLICATIONS WITH ACETYLENE AMMONIA & MERCURY. DO YOU NEED OTHER ASSOCIATED EQUIPMENT? PLEASE SEND US YOUR ENQUIRY



**TYPICAL CUSTOMERS
INCLUDE:**

- + AMEC
- + BP
- + CONOCO PHILLIPS
- + KBR
- + MUSTANG ENGINEERING
- + MODEC
- + SHELL
- + WOOD GROUP
- + 3SUN

Applications: OIL AND GAS

Why Tungum?

Tungum has been in use offshore since 1978. Industry awareness of its superiority for use in marine environments is increasingly evident as far more operators question the use of stainless steel from both safety and economic viewpoints.

Offshore Usage

In salt-laden marine atmospheres, '316' stainless steel is highly susceptible to crevice corrosion and chloride pitting. After just a few years of salt spray exposure, it may still look bright from a distance, but closer inspection, especially under clamps reveals the signs of imminent failure.

Tungum alloy tubing, C69100, possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed surface.

Over time, the tube surface will become discoloured. It may even have a verdigris (green), coating, but under the oxide layer the tube material remains in perfect condition.

Acceptable Media

Typical acceptable media for Tungum Tubing applications: instrument air, tube oil, nitrogen, diesel, heating & cooling medium, potable water, seawater, firewater and hydraulic fluids.

Technical References

Technical references for the applications above are NACE papers 08254 and 10305.

Tungum Tubing is also recommended by BP in their document on Mitigating/Preventing.

External Corrosion in Topside Small Bore Tubing - DWGOM GP 36-15-1.



TUNGUM TUBING IS WIDELY USED IN THE OIL AND GAS MARKET FOR HIGH QUALITY, SAFETY CRITICAL APPLICATIONS.

Applications:

OIL AND GAS

Reasons for using Tungum Tubing in key applications.

- + Excellent anti-corrosive properties give a working life offshore of 30+ years (usually the lifetime of an installation). This gives significant cost savings over the project lifetime.
- + Compatible with all industry accepted tube fittings.
- + Easy to install with no issues on tube bending, assembly and making joints using standard tooling, clamps etc.
- + We have a Worldwide distributor network with readily available stocks of tube. A wide range of sizes in both imperial and metric is available ex-stock.
- + Used alongside Super Duplex and Austenitic Stainless materials such as 6MO, 2507, 317 etc. Tungum provides cost savings on instrumentation pipework for marine systems and non-process hydraulic and pneumatic applications.
- + Its distinctive brass colour means no potential confusion over tube selection during installation or identification at a later date.



TYPICAL APPLICATIONS INCLUDE:

- + HYDRAULIC AND PNEUMATIC CONTROL INSTRUMENTATION SYSTEMS.
- + FIRE FIGHTING (DELUGE) CONTROL AND INSTRUMENTATION LINES.
- + LIFE SUPPORT SYSTEMS.
- + MISCELLANEOUS MARINE AUXILIARY SYSTEMS.
- + PEDESTAL CRANES AND OTHER MECHANICAL HANDLING SYSTEMS.
- + DRILL FLOOR HYDRAULICS AND CONTROLS.
- + IMPULSE LINES.
- + TEMPERATURE SAFETY ELEMENT (TSE) LOOPS.
- + POTABLE WATER SYSTEMS.

TUNGUM TUBING IS USED IN NON-PROCESS HYDRAULIC AND PNEUMATIC SYSTEMS IN THE OFFSHORE OIL AND GAS INDUSTRY.



TYPICAL CUSTOMERS

INCLUDE:

- + AQUA-AIR INDUSTRIES
- + CAL DIVE
- + DRASS GALEAZZI
- + DIVEX
- + GLOBAL INDUSTRIES
- + LEXMAR
- + SEALION
- + SUBMARINE MANUFACTURING
- + SUBSEA 7
- + UNIQUE MARITIME GROUP



Applications:

DIVE SYSTEMS

Typical applications include:

- + Life support & divers heating circuits in saturation and air dive systems.
- + Life support systems within Medical Hyperbaric Centres and Hospitals.
- + Hydraulic control and actuation of Retrieval Systems for submersibles and diving bells.
- + Hyperbaric weld habitats & line-up frames.

Reasons for using Tungum Tubing in key applications:

- + Excellent anti-corrosive properties give a working life offshore of 30+ years (usually the lifetime of an installation). This gives significant cost savings over the project lifetime.
- + Material of choice for Oxygen and Hyperbaric systems.
- + Non-sparking.
- + Compatible with all industry accepted tube fittings – flared, twin ferrule or braze.
- + Easy to install with no issues on tube bending, assembly and making joints using standard tooling, clamps etc.

"We at LexMar have been using Tungum Alloy on our dive systems for over 15 years now without an issue. It is an ideal material for this type of application where O2 compliance and safety critical operations are a must. We recommend the use of Tungum Alloy tubing to all of our clients"

Lexmar on Tungum Tubing – October 2011

TUNGUM TUBING HAS A LONG AND SUCCESSFUL HISTORY OF USE IN MARINE DIVE SYSTEMS APPLICATIONS

Applications:

NAVAL AND COMMERCIAL MARINE

Typical applications include:

- + Hydraulic and pneumatic ring mains on naval ships.
- + Steering gear/stabilisers - hydraulic control & actuation.
- + Deck winch and lifeboat davit system pipe-work.
- + R.A.S. (refuelling at sea) rig control lines.
- + Diving system pipe-work.
- + Aircraft lifts and ammunition hoists.
- + Gun & missile control hydraulics and pneumatics.
- + Deck crane hydraulic lines.
- + Winch, capstan and life boat davit systems.
- + Hatch cover and access door systems.
- + Bow visor, bow & stern door and ramp gear outfits.
- + Trawl system hydraulics lines on fishing vessels.
- + Tank wash-down system pipe-work.
- + Pneumatic actuator systems.

A major mechanical services consultant has given their own 50 year guarantee on a hydraulic system for the Colne river barrage near Colchester because of the long service life of Tungum Tubing.



TYPICAL CUSTOMERS

INCLUDE:

- + BAE SYSTEMS
- + BIBBY OFFSHORE
- + BJ SERVICES
- + CAMMELL LAIRD
- + DAEWOO SHIPBUILDING AND MARINE
- + ELEFSIS SHIPYARDS
- + RNLI
- + SAMSUNG HEAVY INDUSTRIES
- + SEALION
- + STENA
- + SUBSEA 7
- + TECHNIP AND UNIQUE MARITIME GROUP



THE NAVAL AND COMMERCIAL MARINE INDUSTRY HAS MADE GOOD USE OF TUNGUM TUBING IN OVERCOMING THE CORROSION PROBLEMS THEY FACE

Applications:

NAVAL AND COMMERCIAL MARINE

The Naval and Commercial marine industry has made good use of Tungum Tubing in overcoming the corrosion problems they face.

Reasons for using Tungum Tubing in key applications:

- + Excellent anti-corrosive properties give a working life offshore of 30+ years (usually the lifetime of an installation). This gives significant cost savings over the project lifetime.
- + Compatible with all industry accepted tube fittings.
- + Easy to install with no issues on tube bending, assembly and making joints using standard tooling, clamps etc.
- + No recorded failures of Tungum Tubing when correctly used and installed.
- + Worldwide recognised approvals.
- + Material of choice for Oxygen and Hyperbaric systems.
- + Used alongside Super Duplex and Austenitic Stainless materials such as 6MO, 2507, 317 etc.
- + Tungum provides cost savings on instrumentation pipework for marine systems and non-process hydraulic and pneumatic applications.



**MATERIAL OF CHOICE FOR
OXYGEN SYSTEMS**

Applications:

MEDICAL

Tungum Tubing is ideal for use in Hyperbaric medical chambers as it is an excellent antimicrobial material (as a Brass Alloy which contains 84% Copper) with non-sparking features, which makes it ideal for use with oxygen.

Typical applications include:

- + Life support systems within Medical Hyperbaric Centres and Hospitals.

Hyperbaric Medical Chambers

Submarine Manufacturing Ltd. uses Tungum products when manufacturing hyperbaric medical chambers (sometimes referred to as hyperbaric oxygen therapy chambers (HBOT)) as a measure to inhibit the growth of harmful pathogens – bacteria, mould, algae, fungi and viruses.

The most recent hyperbaric chamber from Submarine Manufacturing was installed for NHS Orkney. Tungum Tubing was used extensively on this chamber, both inside and out. This engineering and manufacturing methodology, including Tungum Tubing, gives hospitals the very best hyperbaric solution to meet their needs in the 21st century.

CDA Hospital Trials

The Copper Development Association (CDA) has been carrying out clinical trials at Selly Oak Hospital, part of the University Hospital Birmingham NHS Trust. It concluded that the use of copper alloys could reduce the amount of micro organisms contained on them by 90-100% when compared to standard materials. In the test ward, frequently touched surfaces were identified and replaced with copper containing items including: door handles, push plates, sink taps, grab rails, dressing trolleys, over-bed tables, toilet seats and light switches. These items were used and evaluated over a period of 18 months, in order to observe the effects on environmental microbial loads.



TYPICAL CUSTOMERS INCLUDE:

- + DRASS GALEAZZI
- + SUBMARINE MANUFACTURING
- + IHC HYTECH



Antimicrobial
Copper
Cu+

**GIVING HOSPITALS THE VERY BEST
HYPERBARIC SOLUTION TO MEET THEIR
NEEDS IN THE 21ST CENTURY**

Applications:

MEDICAL

Tungum Tubing is ideal for use in Hyperbaric systems as it is an excellent antimicrobial material (as a Brass Alloy which contains 84% Copper) with non-sparking features, which makes it ideal for use with oxygen.

Reasons for using Tungum Tubing in key applications:

- + Material of choice for Oxygen and hyperbaric systems.
- + Compatible with all industry accepted tube fittings – flared, twin ferrule or braze.
- + Easy to install with no issues on tube bending, assembly and making joints using standard tooling, clamps etc.
- + We have a Worldwide distributor network with readily available stocks of tube. A wide range of sizes in both imperial and metric is available ex-stock.
- + Worldwide recognised approvals.
- + Its distinctive copper colour means no potential confusion over tube selection during installation or identification at a later date.
- + Environmentally friendly due to its long life, a good use of the World's precious resources.



**TUNGUM TUBING IS AN EXCELLENT
ANTIMICROBIAL MATERIAL**

Applications:

DEFENCE

Tungum Tubing is used in many defence applications, including hydraulic and pneumatic pipes.

Long history with the UK MoD

Tungum Alloy tubing has been used by the UK MoD for over 80 years now. It was originally used by the RAF on many planes from the 1930's, but is no longer as other more lightweight materials have now taken its place. However it continues to be utilised in Army fighting vehicles such as Saxon APCs, FV430, AS90 and Challenger 1 & II.

Bofors, Sweden

Tungum has been the material of choice for Bofors in Sweden for many years. The main usage is again on hydraulic systems such as the traverse gear & projectile loading systems. Their Naval "Trinity" gun has been fitted with Tungum Tubing right from the Mk I through to the latest Mk III version. Bofors have recently had their "Archer" land based howitzer ordered by the Norwegian Army. Tungum Tubing is used on the hydraulic systems of this gun.

BAE Systems, UK

Tungum is specified on the hydraulic systems for the M777 being made by UK BAE in Barrow in Furness destined for use by the US military.

BAE Future Rapid Effect System (FRES)

It is also one of the materials chosen for the "FRES" vehicle specification being headed up by General Dynamics.



TYPICAL CUSTOMERS INCLUDE:

- + PROJECTILE LOADING SYSTEMS
- + CONTROL LINES
- + FIGHTING VEHICLE BRAKE PIPES
- + FIGHTING VEHICLE FUEL LINES
- + CLIMATIC CONTROL CIRCUITS
- + TRAVERSE GEAR HYDRAULICS



Applications:

DEFENCE

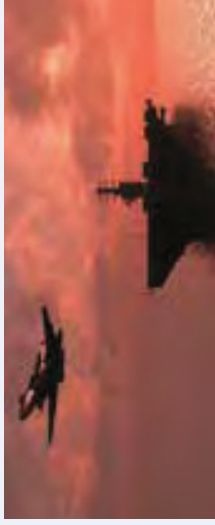
Tungum Tubing is used in many defence applications, including hydraulic and pneumatic pipes.

Reasons for using Tungum Tubing in key applications:

- + Excellent fatigue and shock resistance.
- + Compatible with all industry accepted tube fittings.
- + Resistant to corrosion.
- + Over 80 years' experience of Tungum Tubing applications.
- + Reduced system down times due to its longer life.
- + Easy to install with no issues on tube bending, assembly and making joints using standard tooling, clamps etc.
- + Worldwide recognised approvals.
- + Guaranteed for life. Standard terms and conditions apply for use and installation, available upon request.

Defence Specifications:

- + Army AFS 4000
- + Navy Defence Standard 02 749 Part 3 and 02-878
- + Aircraft DTD 253A & DTD 5019



**EXCELLENT FATIGUE AND
SHOCK RESISTANCE**

Applications:

TRANSPORTATION

Tungum has been used in transportation applications for many years. The corrosion resistance and excellent anti-fatigue properties of Tungum Tubing make it the material of choice for many transportation manufacturers.

Typical applications include:

- + Brake lines.
- + Suspension systems.
- + Fire suppressant systems.
- + Control lines.

The reasons Tungum tubing is specified for these applications are:

- + Excellent fatigue and shock resistance.
- + Compatible with all industry accepted tube fittings.
- + Resistant to corrosion.



TYPICAL CUSTOMERS INCLUDE:

- + BAE SYSTEMS
- + BOMBARDIER
- + TRANSPORTATION
- + BRUSH TRACTION
- + MOD
- + PULLMAN RAIL
- + STAUFF UK



**TUNGUM. CHOSEN FOR SAFETY
CRITICAL APPLICATIONS**

04



: INSTALLATIONS

Offshore Oil and Gas

OFFSHORE OIL AND GAS

Examples of offshore installations utilising corrosion resistant Tungum Tubing

In salt-laden marine atmospheres, '316' stainless steel is highly susceptible to crevice corrosion and chloride pitting. After just a few years of salt spray exposure, it may still look bright from a distance, but closer inspection reveals tell-tale signs of imminent failure to hold pressure.

Tungum Tubing possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed surface, no more than two thousandths of an inch thick, when complete.

The tube becomes discoloured, it may even have a verdigris coating, but under the oxide layer the tube material is perfect and will remain so for the lifetime of the installation.

Talisman Sinopec	Clyde, Piper Bravo and Saltire Platforms
Total	Dunbar Platform
BP	SSV Iolair, Schiehallion FPSO, Mad Dog, Atlantis, Holstein, Marlin, PSVM, Shah Deniz 2 platforms
Apache	Uncle John
Nexen	Buzzard Platform
Qatar Gas	North Field platform
Chevron	Captain platform
Shell Platforms	Southern Basin Revamp, Sole Pitt Clipper, Stadive DSV, Golden Eye, Sakhalin Isle, Ursa
Taqa	Eider and Tern
Sealion	DSV's
Technip	DSV's
Subsea7	DSV's and FPSO
Baker Hughes	Blue Dolphin DSV
Williams	Gulfstar 1
Hess	Stampede
Petronas	PFLGN2
Noble	Gunflint



**TUNGUM TUBING, POSSESSES
A NATURAL PROTECTION MECHANISM**

005



: CASE STUDIES

01 : Oilfield Services Vessel

08 : Tower Bridge, London

02 : Diving Support Vessel

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**NO RECORDED FAILURES
OF TUNGUM TUBING**

CASE STUDY : 01

Oilfield Services Vessel

Reducing risk of corrosion failure on hydraulic, potable water and chemical lines

By selecting Tungum Tubing a leading deepwater project company was able to reduce the risk of tube line failure due to saltwater corrosion while also cutting downtime and refit costs.

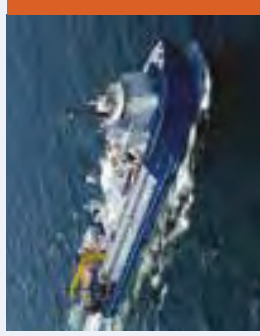


Fig.1



Fig.2



Fig.3

Fig 1. BJ Blue Dolphin – Oilfield Services Vessel.

Fig 2. Tungum Tubing (top) remains unscathed despite more than 10 years marine exposure on a semi-submersible support vessel. Stainless steel (bottom) showed both crevice and chloride pitting after barely five years in the same environment.

The Challenge

In 2009 a leading deepwater project company BJ Services (a Baker Hughes incorporated company) was building a new oilfield services vessel - the Blue Dolphin. On previous vessels they had experienced corrosion problems after using stainless steel tubing for the hydraulic, potable water and chemical tube lines. To transfer chemicals to the mix tanks the lines leave the protection of the vessel and are exposed to a salt water environment.

As a result of the corrosion and resultant leak points, they had to replace stainless steel tubing multiple times on previous vessels at considerable cost and downtime.

The Tungum Solution

Baker Hughes chose Tungum Tubing for its proven history in seawater environments and its resistance to stress and crevice corrosion. The tube possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed service, no more than two thousandths of an inch thick, when complete. The tube becomes discoloured and it may even have a verdigris coating, but under the oxide layer the tube material is perfect and will remain so for a very long time.

The Result

Baker Hughes replaced the corroded lines with Tungum and was pleased with the performance of the tubing. Tungum Tubing now plays a major role in eliminating downtime of many systems in this vessel as it is highly resistant to seawater and its atmosphere, resisting both stress and crevice corrosion to offer outstanding serviceability, even at intermittent duty in the highly corrosive 'splash zone'.

Fig 3. Tungum Tubing lines on BJ Blue Dolphin.

CASE STUDY : 02

Diving Support Vessel

Reducing risk of corrosion failure on instrumentation lines

By selecting Tungum Tubing a leading deepwater project company was able to reduce the risk of tube line failure due to saltwater corrosion while also cutting downtime and refit costs.



Fig.1

The Challenge

In 1983 a leading deepwater project company Subsea 7 was building a new diving support vessel – Rockwater 1. On previous vessels they had experienced corrosion problems using stainless steel tubing for the instrumentation lines. Various lines run externally and are exposed to a salt water environment. As a result of the corrosion and resultant leak points, they had to replace stainless steel tubing multiple times on previous vessels at considerable cost and downtime.



Fig.2

The Tungum Solution

Subsea 7 chose Tungum Tubing for its proven history in seawater environments and its resistance to stress and crevice corrosion. The tube possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed service, no more than two thousandths of an inch thick, when complete. The tube becomes discoloured and it may even have a verdigris coating, but under the oxide layer the tube material is perfect and will remain so for a very long time.



Fig.3

The Result

Subsea 7 installed Tungum for the instrumentation lines and was pleased with the performance of the tubing. Tungum Tubing now plays a major role in eliminating downtime of many systems in this vessel as it is highly resistant to seawater and its atmosphere, offering outstanding serviceability, even at intermittent duty in the highly corrosive 'splash' zone. The photo on the right was taken in 2010 and shows the tube still in good condition and performing well after 26 years of service!

Fig 1. Rockwater 1 – Diving Support Vessel.

Fig 2. Tungum Tubing remains unscathed despite more than 10 years marine exposure on a semi-submersible support vessel. Stainless steel (bottom) showed both crevice and chloride pitting after barely five years in the same environment.

Fig 3. Tungum Tubing lines after 26 years on Rockwater 1.

CASE STUDY : 03

Modular Diving Saturation Systems

Oxygen Compatibility and DNV Compliance on Gas Ring Panels, Oxygen Lines and Divers Air Systems

By selecting Tungum Tubing a leading modular saturation dive system company was able to ensure full oxygen compatibility and meet stringent build requirements in accordance with DNV rules.



Fig 1. Tungum Tubing installed on a saturation diving system module.

Fig.1

The Challenge

With more than 40 saturation systems delivered worldwide, Drass Galeazzi is the world-recognised leader of Saturation Diving System design, manufacture and installation. In 2005 they needed to introduce a DNV approved high quality tubing offering corrosion resistance and oxygen compatibility for use on the gas ring panels, oxygen lines and divers air systems. They needed a proven product which would meet DNV rules and perform continually and reliably in this demanding safety critical application.

The Tungum Solution

Drass chose Tungum for its excellent features and benefits including:

- + *High corrosion resistance to sea water and its atmosphere*
- + *Clean bore feature which makes it ideal for hydraulic and pneumatic applications*
- + *Lasting "clean bore" properties and oxygen compatibility*
- + *Non-magnetic and non-sparking properties*
- + *Excellent thermal conductivity*

These features and benefits have proved invaluable in piping high pressure gases, particularly oxygen where Tungum's thermal conductivity / diffusivity characteristics virtually eliminate the dangers of explosions taking place.

The Result

Since introducing Tungum Tubing in 2005 it is now the material of choice for Drass their systems with no recorded failures.

CASE STUDY : 04

World War II Aircraft Restoration

Tungum Tubing has been used on the hydraulic systems of seven flying aircraft restored by Hawker Restorations Limited to original manufacturing specifications



Fig.1



Fig.2



Fig.3

Fig 1. Tungum Tubing installed on a Hawker Hurricane G-HHII in the 1940's and again in 2009!

Fig 2/3. Close up images of the Tungum Tubing. Courtesy of Hawker Restoration Ltd.

The Story

At the end of her military service the Hawker Hurricane G-HHII was refurbished to 'as new' condition and then sold off to the private sector, as were most surviving RCAF Hurricanes at that time. Many became much needed 'hardware stores' donating their parts to keep the tractors and machinery running on the many enormous farms of the Canadian prairie. This aircraft was lucky and remained substantially intact, to be re-discovered in Canada in the 1990's as a very complete airframe with most major components intact. Returning to the UK, Hawker Restorations Limited began the restoration work in 2005. The comprehensive restoration was completed in January 2009 and her first flight took place from North Weald on 27 January 2009.

How Tungum played its part

The Civil Aviation Authority requires items to be made as the original manufacture of aircraft in and during World War II and Tungum is used on the hydraulic systems of the aircraft. Its Tungum is an ideal material for this type of application. Its high strength to weight ratio made it a material of choice at the time. Fatigue resistance is another important feature of Tungum as there is a large amount of vibration that hard piping systems have to endure on early aircraft such as the Hurricane. Tungum Tubing is performing well with no reported problems on the restoration. Positive feedback was also received on how easy the tube is to work with and assemble. Hawker Restoration Limited has used Tungum on seven previous restoration projects.

CASE STUDY : 05

Nuclear Application



Tungum Tubing installed in Hunterston Power Station.

Tungum Tubing is utilised in non-process salt water corrosion resisting applications in the Hunterston B Nuclear Power Station

The Challenge

Tungum Alloy is a material that excels in harsh environments. It is ideal for the applications where the material has to withstand pitting and crevice corrosion. The main applications are for the use in non-process salt water. In salt-laden marine atmospheres, 316 stainless steel for example, is highly susceptible to crevice corrosion and chloride pitting. After just a few years of salt spray exposure, it may still look bright from a distance, but closer inspection reveals tell-tale signs of imminent failure to hold pressure.

The Tungum Solution

Tungum Alloy Tubing combines excellent corrosion resistance, unusually high strength to weight ratio, ductility and first class fatigue properties. Highly resistant to salt water and its atmosphere, Tungum resists both stress and crevice corrosion to offer outstanding serviceability. Tungum alloy possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed surface, no more than two thousandths of an inch thick, when complete. The tube becomes discoloured, it may even have a verdigris coating, but under the oxide layer the tube material is perfect and will remain so for the lifetime of the installation.

The Result

Tungum Alloys non-magnetic and non-sparking properties make Tungum invaluable in piping high pressure gases, particularly oxygen where its thermal conductivity/diffusivity characteristics virtually eliminate the potential dangers present when materials are employed. Tungum alloy is also a cryogenic material, suitable for chemical engineering and low temperature processes. Its corrosion resistance often enables its use in conveying fluids and gasses containing corrosive elements. Tungum Tubing is being used for non-process applications in Nuclear power plants to resist pitting and crevice corrosion. It is utilized on sea water systems such as impulse lines. Tungum Alloy is approved by Westinghouse, Babcock & EDF Energy.

CASE STUDY : 06

FPSO Subsea Solution

Espoir FPSO topside production facility for oil & natural gas supplier 3Sun Limited

By selecting Tungum Tubing, 3Sun Limited were able to reduce the risk of tube line failure due to saltwater corrosion.



Fig.1

The Challenge

Espoir, CNR, is a leading production facility for oil & natural gas for Cote d'Ivoire, located 19 km offshore of Jacqueville, 60 km southwest of Abidjan, in water depths ranging from 100m to 600m. Hydraulic and pneumatic instrumentation tubing, 316 Stainless Steel was being used and showing signs of corrosion.



Fig.2

The Tungum Solution

3Sun Limited chose Tungum Tubing for its proven track record in seawater environments, its resistance to pitting and crevice corrosion. The tube possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed service, no more than two thousandths of an inch thick, when complete. The tube becomes discoloured and it may even have a verdigris coating, but under the oxide layer the tube material is perfect and will remain so for the lifetime of the vessel.



Fig.3

The Result

3Sun Limited have been installing Tungum since they started working on this project in 2010, due to the excellent properties Tungum can offer to the offshore environment.

Fig 1, 2 & 3. The Espoir Ivorian FPSO in the Espoir Field, off the Ivory Coast.

CASE STUDY : 07

Wellington Bomber Services

Hydraulic and breathing air services in the Wellington Bomber

Tungum Alloy's first major application was in tube form for the various hydraulic and breathing air services in the Wellington Bomber.



Fig.1



Fig.2

Fig 1 & 2. Thank you to Brooklands Museum photo archive for the use of the two photographs.

The Tungum Solution

One of the early Tungum Alloy applications was in tube form for use on the various hydraulic and breathing air services for the Wellington Bomber. The reason for using Tungum was because of its extremely good resistance to fatigue and its high strength to weight ratio. Thereafter, it was extensively used throughout the R.A.F.'s "fleet" until the jet aircraft "TSR2" was abandoned in 1965. By then the Army and Navy had adopted Tungum Tubing as being the material of choice for these types of arduous applications.

Ditching in Loch Ness

On New Year's Eve in 1940 a training flight went horribly wrong when a Wellington NZ980 Bomber suffered engine failure. Most of the crew were ordered to bail out, leaving the Captain and a second pilot to deal with the failing aircraft. Luckily, the pilots spotted a nearby body of water and managed to make a perfect landing on Loch Ness - bailing from the bomber before it vanished beneath the water. Aside from one fatality, when a parachute failed to open, the crew survived the ordeal.

The plane, unfortunately, was lost beneath the waters of the Loch. The wreck had lain beneath the water for almost 45 years before divers stumbled across the wreckage in almost perfect condition. It was finally recovered from its watery bed in September, 1985. The aircraft is now in Brooklands Museum, Weybridge and is one of two Wellington Bombers still intact.

**Tungum Tubing
is installed in the
Bascule Chamber
of the Tower
Bridge, London**

CASE STUDY : 08

Tower Bridge, London



The Challenge

One of the most iconic structures in London and recognized around the world is Tower Bridge. The hydraulic systems were totally revamped some 25 years ago in an attempt to bring the antiquated bridge lifting and lowering mechanism in to the 21st century. Tungum Alloy tubing was the material of choice to ensure a further hundred years of trouble free hydraulic operation.

The Tungum Solution

The fact that Tungum has superior corrosion resistance in high humidity applications and extremely good fatigue properties makes Tungum an ideal choice. You can imagine the heavy loads and stresses that go through the bridge's structure and mechanics. With the constant vibration of London's busy traffic rumbling overhead our Tungum Alloy tubing is an ideal choice for this type of application. When fatigue and corrosion resistance are an issue, Tungum Alloy is an ideal choice.

The Result

Tungum Tubing installation is performing brilliantly with no reported problems for over 25 years!

Tungum Tubing is used for hydraulic and pneumatic military applications

CASE STUDY : 09

Tungum in the Military



Fig.1

Tungum Alloy tubing has been used by the UK MoD for over 60 years. The main areas of use are for hydraulic and pneumatic applications in the Army and Navy.

It was used by the RAF, but is no longer as other more lightweight materials have now taken its place. In salt-laden atmospheres such as tracks and roads, '316' stainless steel for example, is highly susceptible to crevice corrosion and chloride pitting. After just a few years of salt spray exposure, it may still look bright from a distance, but closer inspection reveals tell-tale signs of imminent failure to hold pressure.



Fig.2

Tungum alloy, however, possesses a natural protection mechanism whereby, on exposure to salt spray, a very thin oxide coating is generated over the exposed surface, no more than two thousandths of an inch thick, when complete.

The tube becomes discoloured, it may even have a verdigris coating, but under the oxide layer the tube material is perfect and will remain so for the lifetime of the installation.

Tungum continues to be utilised in UK Army fighting vehicles such as: Saxon APCs, FV430, AS90 & Challenger I & II.

Tungum has been the material of choice for Bofors in Sweden for many years. The main usage is on the hydraulic systems. Mainly the traverse gear & projectile loading systems.



Fig.3

Their Naval "Trinity" gun has been fitted with Tungum Tubing right from the Mk I through to the latest Mk III version. Bofors have recently had their "Archer" land based howitzer ordered by the Norwegian Army; Tungum is used on the hydraulic systems of this gun.

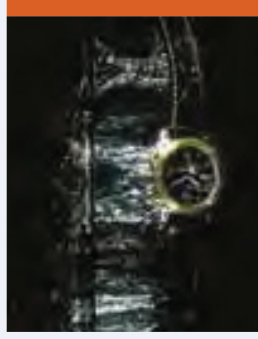
Tungum is specified on the hydraulic systems for the M777 being made by UK BAE in Barrow in Furness destined for use by the US military. Tungum is also one of the materials chosen for the "FRES" vehicle specification being headed up by General Dynamics.

Fig 1. Warrior armoured carrier.
Fig 2. Bofors 'Trinity' gun.
Fig 3. BAE M777.

One of our customers liked Tungum so much, they decided to make a watch using Tungum.

CASE STUDY : 010

Tungum in the Drass Dive Watches



Information and photos courtesy of Drass.

Special Edition

Drass are a leading specialist company in the diving world and have used Tungum Tubing in their hyperbaric chamber construction for many years. Drass liked the performance value and history of Tungum so much they decided to produce some special edition Tungum watches. Drass watches express the sense of belonging to the diving, subsea and offshore world. An environment where man and technology share the need for strength, performance and reliability. Where experience and tradition is as valued as innovation.

Tungum Watch

The Tungum watch features a new original solid case in Tungum – manually polished. Stainless steel helium valve, watch face coloured with special matt blue, automatic movement, calibre sw 200 – Swiss made, 26 jewels incabloc shock protection, blue leather strap. Water resistance to 1000 metres.

Tungum SatDive Watch

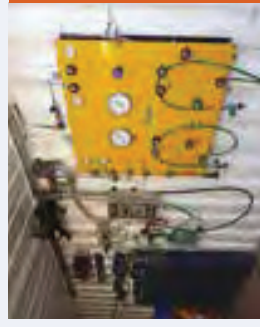
The Tungum SatDive watch features a stainless steel solid case, sanded and polished in PVD with Bezel in polished Tungum. Stainless steel helium valve, watch face with special matt colours, automatic movement, calibre sw 200 – Swiss made, 26 jewels incabloc shock protection, leather strap. Water resistance to 1000 metres.

**FOR MORE INFORMATION, PLEASE VISIT:
WWW.DRASSWATCH.COM**

CASE STUDY : 011

Dive Centre - Trimix / Nitrox Gas Mixing System

**Tungum Tubing
being used in a
Trimix / Nitrox gas
mixing system for
Cromhall Dive Centre**



*Photographs courtesy of
Simon Chen at Cromhall
Diving Centre.*

Where and why Tungum is used

Cromhall Diving Centre is the UK representative for the LM-NT Continuous Process blending systems that supply pre-mixed low pressure O₂ / He to the compressor for direct filling of diving cylinders with Nitrox (max 40%) and Trimix.

The diving cylinders do not need to be oxygen cleaned to fill with this process and the system eliminates the risks of partial pressure blending.

Cromhall Dive Centre

Cromhall Quarry is 9.5 acre body of water just off the M5 north of Bristol. The slightly undulating rock bottom gives an ideal training depth of 17 metres. At the north end of the quarry is a pontoon floating in 15 metres of water that has been specifically designed for ease of use by divers. The former limestone quarry has filled naturally, with underwater visibility during April 2011 of up to 5-6 metres, which is expected to rise to 8-10 metres during the Summer. Tungum Tubing is performing well with no reported problems in the gas mixing system. Positive feedback was also received on how easy the tube is to work with and assemble.

For information of the dive centre please visit their website:
www.cromhall.com/diving

CASE STUDY : 012

Tungum in H2O watch GmbH - Dive Watches

H2O watch GmbH have made a watch using Tungum due to its corrosion resistance in the marine environment!

H2O watch GmbH are a leading dive watch manufacturer, developing and manufacturing custom products. Their goal is to create an innovative, customizable dive watch, inspired by some vintage and modern design elements.



Photo's courtesy of Clemens Helberg at H2O watch GmbH.
Text by OceanicTime for H2O watch GmbH.

Why do H2O use Tungum for their dive watches?

Apart from being an incredibly attractive material with a lustrous appearance of 22 carat gold; Tungum alloy is well suited to marine environments. It is non-magnetic and non-sparking and is highly corrosion resistant to seawater and develops over time a wonderful patina. The Kalmar Tungum Fixed Bezel features a Tungum case, bezel, crown guard and custom CNC machined buckle. The crown and exhibition case-back are made from DLC coated Titanium.

H2O Kalmar Tungum Fixed Bezel

This is our first diver's model made from this exciting material. We had never really considered anything with a gold finish for H2O Watches, but when I was first introduced to this exotic alloy and saw for myself how lustrous it was and how luxurious its appearance was it made me think again. The fact that Tungum was also suitable for use in marine environments, owing to its high resistance to saltwater made it all the more appealing as a possible material for our watch-line. As with our new Mokume Gane Fixed Bezel diver, the Tungum version also utilizes the same basic case design of our original Titanium Kalmar. It shares its 45mm case diameter and 3000 meters of water-resistance. The case design has in fact been officially certified by an independent German company specializing in deep sea equipment to 6000 meters. Although still extreme dive watches; it was our aim that both new models would be introduced as more formal or dressy models, which we believe has been achieved through the minimal look of our 'Fixed Bezel' system. However we also believe that we have retained many of the functional and aesthetic aspects of the original H2O Kalmar such as its dial, hands and case.

**FOR MORE INFORMATION,
PLEASE VISIT:
WWW.H2O-WATCH.COM**

CASE STUDY : 013

HERA Transferable Saturation Diving System

Tungum Tubing has been used in the panel for a life support package for HERA Transferable Saturation Diving System



Photo's courtesy of Impresub International

The Client

IMPRESUB INT'L is a leading company in the provision of a complete range of offshore services such as diving (air and saturation gas), R.O.V. (Remote Operated Vehicle) Services, trenching and post-trenching activities of laid pipelines and electrical cables, offshore inspections, repair and maintenance of offshore structures (platforms, wells, flow Lines).

The HERA Fly-Van

Tungum has been used in the panel for a life support package for HERA transferable saturation diving system. Tungum Tubing in sizes 1 1/2" and 1 1/4" is used for pressurization and exhaust lines on the saturation control panel. This control panel will be connected to a HRC (Hyperbaric Rescue Chamber). The system will work with oxygen / helium gas mixes. Tungum was installed in October/November 2011, in conjunction with Swagelok fittings. Impresub International LCC used Tungum Tubing as they had good previous experience with it on their diving equipment.

The Result

Tungum Tubing is performing well with no problems. During testing it was tested at 90 barG over working pressure and 24 hours leak test @60 barG with helium with no reported problems. Positive feedback was also received on how easy the tube is to work with and assemble, and the good results achieved with the Swagelok fittings.

006



: TECHNICAL DATA

Accreditations

Technical Specifications

Physical Properties

Chemical Composition

Temperature Characteristics

General Corrosion Resistance

Corrosion Resistance Offshore

NACE Corrosion Resistance Testing

ACCREDITATIONS, APPROVAL AND DESIGNATIONS

Tungum Ltd is totally dedicated to the concept of quality. The Quality Management System is approved to BS EN ISO 9001.

We see this as a clear endorsement of our robust operating procedures which are dedicated to delivering the high levels of products and service our customers have come to expect. DNV already carries out third party inspection checks of our Tungum Tubing on behalf of customers and is an internationally recognised name in our major tube market sectors.

Tungum Alloy tubing has the approval of:

- + ASME B31.1 and B31.3
- + NORSOK M-650
- + USCG – United States Coast Guard
- + Lloyds Register of Shipping
- + DNV-GL



+

Tungum has passed extensive testing and is segment defined for mitigating and preventing external corrosion on topside small bore tubing.

Tungum tubing has been specified and used on many projects with companies such as:

- + AIR LIQUIDE
- + AIR PRODUCTS
- + AMEC
- + BAE
- + BECHTEL
- + BOC
- + BOMBARDIER
- + BP
- + CONOCO PHILLIPS
- + DRASS
- + HESS
- + JGC
- + KBR
- + MOD. UK
- + MODEC
- + PRAXAIR
- + SHELL
- + SUBSEA7
- + TECHNIP
- + WILLIAMS

TECHNICAL SPECIFICATIONS

Tungum Tubing meets the following specifications

- + BS EN 12449 CW700R, Cond. R430.
- + American Standard ASTM B706-00 Temper. TF00 identified as Copper Alloy UNS No. C69100.
- + ASTM G124-10 Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres.
- + Ministry of Defence Specifications: Def. Stan. 02-749 Part 3 or NES 749 Part 3, Def. Stan. 02-833 or NES833, Army: AFS-4000 DTD5019 (for H.P. Systems) DTD253 A (for L.P. Systems) Tungum in-house specification is TCL100 (copy available on request).
- + Tungum Alloy is Eddy current tested as standard in accordance with the requirements of BS 3889 and ASTM E:243.
- + Further hydraulic pressure testing can be carried out at the customer's request within the capabilities of the tube. Unless otherwise specified this is typically at 1.5x the maximum working pressure.

Some of the standards only apply to certain tube sizes or special mill orders. Please check with us before ordering.



PHYSICAL PROPERTIES:

Mechanical, electrical & thermal

MECHANICAL PROPERTIES	REFERENCE	UNIT OF MEASURE	VALUE
Ultimate Tensile Strength	Min value for BSEN12449 CW700R R430	N/mm ²	430
	Min value for ASTM B706-00 Temper TF00	N/mm ²	420
	Min value for Def. Stan. 02-749	N/mm ²	450
0.2% Proof Strength	Min value for BSEN12449 CW700R R430	N/mm ²	220
	Min value for ASTM B706-00 Temper TF00	N/mm ²	214
	Min value for Def. Stan. 02-749	N/mm ²	230
Elongation	Min value for BSEN12449 CW700R R430	% on 5.65 √ A	40
	Min value for ASTM B706-00 Temper TF00	% on 5.65 √ A	40
	Min value for Def. Stan. 02-749	% on 5.65 √ A	40
Hardness	Range for BSEN12449 CW700R R430*	HV5	125 - 140
	Range for ASTM B706-00 Temper TF00*	HRB	69 - 76
	Range for Def. Stan. 02-749	HV5	125 - 140
Modulus of Elasticity	In Tension or Compression In Tension or Shear	N/mm ²	116.5 x 10 ³
		lb per sq. in.	16.9 x 10 ⁶
		N/mm ²	43.8 x 10 ³
		lb per sq. in.	6.35 x 10 ⁶
Poisson's Ratio			0.33
Ultimate Shear Strength		N/mm ²	253
		Tons per sq. in.	16.4
Yield Point in Shear		N/mm ²	143
		Tons per sq. in.	9.3
IZOD Impact Value		J.	41.7
Density		g/cm ³	8.52
			8.52 x 10 ⁻⁶
		lb per cu. in.	0.308
ELECTRICAL PROPERTIES			
Electrical Conductivity at 20°C		Referred to Copper	15% ± 5%
Specific Resistance at 20°C		Microhms per mm	1.13
Electromechanical Equivalent		Kg per coulomb	32.4
Solution Potential		mV Calomel scale	230
Magnetic Permeability		μ	1.0015
THERMAL PROPERTIES			
Melting Temperature		°C	1008
Stress Relieving Temperature		°C (for 15/20 mins.)	300
Solution Treatment Temperature		°C (for 60 mins.)	800
Thermal Conductivity		W/m°C	77 at 100°C 103 at 300°C
Coefficient of Thermal Expansion		Per°C	19 x 10 ⁻⁶

+ 043

*Not required by specification. Supplied for general information and assistance in testing only.

CHEMICAL COMPOSITION AND GALVANIC SERIES

Galvanic Series

SUBSTANCE	POTENTIAL mV
Magnesium	1730
Mg-4% Al Solid Solution	1680
Galvanised Iron	1140
Cd-Zn Solder (71/29)	1120
Mg5Al8	1070
Zinc	1050
Man22	1040
Al-4% Zn Solid Solution	1020
Al-Zn-Cu Alloy 3L5	990
Al-1% Zn Solid Solution	960
Al-4% Mg Solid Solution	870
Cd-Plated Steel	850
MnAl6	850
Aluminium (99.95%)	850
Al-Zn-Mg-C u-Ni Alloy R R 77	840
Al-Zn-Mg-C u-Cr Alloy 75\$	840
Aluminium (90.0%)	830
Al-11.9% Si Alloy N2	830
Al-1% Mn Alloy N3	830
Al-1% Mg Si Solid Solution	830
Al-Si-Cu-Ni-Fe Alloy DTD.133B	810
Clad H14 Alloy	810
Mild steel 353	780
Grey Cast Iron	780
Tinplate	740
Al-7% Mg Alloy	690
Al-4% C u Solid Solution	690
Al-C u-Mg-Mn Alloy H14	680
Iron (pure)	580
FeAl3	560
Tinman's Solder	560
Lead	550
C u Al2	530
Tin	500
Brass (60/40)	330
Aluminium Brass	290
Silicon	260
Cupro-Nickel (70/30)	260
Tungum Tubing	250
Copper	220
Stainless Steels (316 =195mV)	130 – 430
Alloy 400	170
Nickel	140
Silver	80
Graphite	5
Gold	0
Platinum	0

Galvanic Series of Engineering Materials

The table on the left shows the relative position of Tungum Alloy to other well known materials when placed in galvanic series.

In general significant galvanic corrosion does not take place when copper is coupled to its alloys or when different copper alloys are in contact with each other. The amount of galvanic corrosion on a less noble metal will depend on the relative areas of the two metals in contact and the potential or voltage existing between them in a given environment.

Tungum Alloy Chemical Composition

The chemical composition table on the far left shows the breakdown for the Tungum Alloy used in our tubing.

Chemical Composition

ELEMENT	PER CENT	
	MIN	MAX
Copper	81.00	84.00
Aluminium	0.70	1.20
Nickel	0.80	1.40
Silicon	0.80	1.30
Iron	-	0.25
Lead	-	0.05
Tin	-	0.10
Manganese	-	0.10
Total - other impurities	-	0.50
Zinc	The Remainder	

Note: N.E.S. & D.T.D. specifications vary. Please contact us for more details.

TEMPERATURE CHARACTERISTICS:

Elevated Temperature Test Results

Elevated Temperature Characteristics

The Elevated Temperature Test Results chart show how Tungum alloy performs at elevated temperatures. We are particularly looking to see if the UTS levels at 250°C or 480°F are affected.

Cryogenic Characteristics

Tungum Alloy satisfies many low temperature and cryogenic applications. The mechanical properties of the Alloy all improve with a reduction in temperature, down to as low as - 196°C. The impact resistance also remains substantially unchanged over the same temperature range.

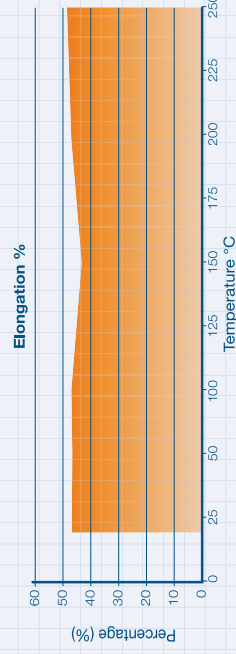
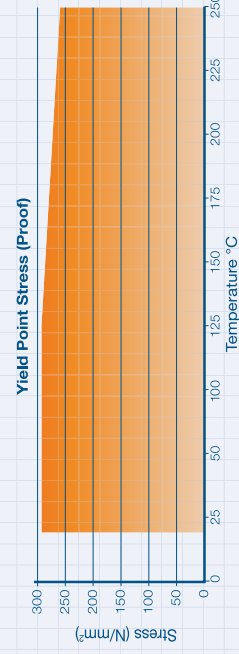
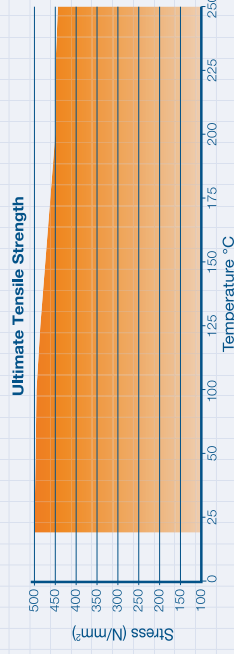
Fatigue Characteristics

As would be expected of a material originally developed for use in hydraulic control systems of aircraft, Tungum alloy tubing has excellent fatigue resisting properties. Pulsing pressures and vibration are recognised as being a major factor influencing the integrity and performance of all hydraulic systems irrespective of the application. Bending of tubing is often carried out as part of the installation process. When you bend tube, the outer wall of the tube becomes thinner and the inner wall becomes thicker. The severity of this depends on the radius of curve and the angle set i.e. 45° or 90° bends. The tube also becomes oval due to the forming operation. The radius and the angle of the bend, the ovality of the tube and the mechanical properties of the tubing material, all influence its fatigue life.

Temp (°C)	UTS (N/mm ²)	Yield (N/mm ²)	% Elong
Room	499	289	46
50	495	287	46
100	492	290	47
150	478	284	44
200	457	271	47
250	443	262	49

Material tested 12mm Outside Diameter x 1.6mm Wall Thickness - Material Test Report Heat Numbers: K64626, K66594 and K67909. Test certificate results Exova - B301625, B301626 and B301627.

Figures are average of results obtained from three different heat numbers.



GENERAL CORROSION RESISTANCE

Tungum has excellent Anti-Corrosion Properties

Tubing: Corrosion Resistance Offshore
The environmental conditions in which engineering products have to operate are by their nature fairly arduous.

None poses greater or wider problems than sea water and the associated saline atmosphere. The life expectancy of equipment is often drastically reduced. In areas where corrosion has already taken place, predicting failure as a basis for preventative maintenance is difficult if not impossible.

At its most aggressive, in the presence of oxygen, sea water attacks most 'standard' materials in a variety of differing but equally costly ways: -

CARBON STEELS

Prove almost impossible to protect and corrode away almost immediately.

COMMON COPPER ALLOYS

Often suffer a shortened life, either as a result of dezincification or stress corrosion.

STAINLESS STEELS - 304, 316

Are highly prone to chloride pitting a particularly damaging form of crevice corrosion producing small holes in material having an otherwise sound appearance.

Super Duplex and Austenitic Stainless Steels - 904L, Monel, 6Mo-Alloy 400, and 2507

Although these materials are far more corrosion resistant, than St. Steels, they are not corrosion proof and do suffer pitting and crevice corrosion after time.

Tungum alloy tubing C69100

Tungum Tubing has been developed to counter the problems of sea water corrosion and in practice has already done so for over 40 years.

Whether totally immersed, or in the highly active 'splash' zone, Tungum alloy tubing gives exceptional resistance to the effects of a marine environment.

Unaffected by either pitting or crevice corrosion, Tungum alloy tubing is protected by its oxide coating. This oxide coating quickly repairs itself if damaged.

These ratings are the result of laboratory tests conducted in-house under the controlled conditions noted. They are published for guidance only. Where any doubt exists, samples of Tungum are freely available for field trials to replicate the precise operating conditions. Tungum Tubing has a high level of general corrosion resistance, allowing it to be specified for use in systems containing, or operating in the presence of a variety of substances and solutions.



NOTE: TUNGUM TUBING SHOULD NOT BE USED IN THE PRESENCE OF ACETYLENE, AMMONIA OR MERCURY.

CORROSION RESISTANCE OFFSHORE

Seawater and the Associated Saline Atmosphere

Of the environmental conditions in which engineering products daily have to operate, none poses a greater or wider problem than sea water and the associated saline atmosphere. The life expectancy of equipment is often drastically reduced and in areas where corrosion has already taken place, predicting failure as a basis for preventative maintenance is difficult if not impossible.

At its most aggressive, in the presence of oxygen, sea water attacks most 'standard' materials in a variety of differing but equally costly ways: -

CARBON STEELS

Prove almost impossible to protect and corrode away almost immediately.

COMMON COPPER ALLOYS

Often suffer a shortened life, either as a result of dezincification or even stress corrosion.

STAINLESS STEELS

Are highly prone to chloride pitting a particularly damaging form of crevice corrosion producing small holes in material having an otherwise sound appearance.

Tungum Tubing has been developed to counter the problems of sea water corrosion and in practice has already done so for over 40 years. Whether total immersed, or in the highly active 'splash' zone Tungum Alloy affords exceptional resistance to the effects of a marine environment. Unaffected by either stress or crevice corrosion, Tungum Alloy is protected by a self generated oxide coating which, once formed, prevents further attack. If this oxide coating is damaged it does of course quickly repair itself.

Protective Oxide Coating

The special corrosion resisting characteristics of Tungum Alloy tubing, carefully developed for use in the hydraulics systems of marine aircraft remains just as valid in todays polluted sea waters.

Corrosion Allowance: As a result of the excellent corrosion resistance characteristics and integrity management feedback received, a corrosion allowance is not generally required for Tungum Tubing when used in suitable applications.



Tungum Tubing remains unscathed despite more than 10 years marine exposure on a semi-submersible support vessel. The Stainless Steel section, from a southern North Sea platform, shows both crevice corrosion and chloride pitting after barely 5 years in the same environment.

NACE CORROSION RESISTANCE TESTING



The image is an example of Tungum Tubing after 10 years at sea on a dredger. Only the grime and oxide coating has been removed from the tube exterior.

This paper compares various metallic materials including 316L, 317LMN (UNS S31726), Alloy 825 (UNS N08825), 6Mo (UNS S31254), Alloy 625 (UNS N06625) and Tungum Alloy (UNS C69100) and underpins the historical evidence of successful performance in these demanding safety critical applications.

Materials were laboratory tested in a cyclic salt fog chamber to ASTM D5894 at temperatures ranging from 25 to 45°C and also field tested by exposure to a marine environment for a one year duration on board two offshore platforms; one located in the Gulf of Mexico and the other in Trinidad. In the laboratory tests Tungum Alloy (UNS C69100) was the material that resulted in the best localized corrosion resistance judging by two of the three visual inspection indicators (pit depth in the body of the tubing and crevice corrosion depth). Conclusions were that Tungum Alloy (UNS C69100) is a material that can be safely used in a marine atmosphere keeping in mind its pressure and internal corrosion limitations.

The results of the test were published in NACE Paper No. 10305 and presented at the NACE CORROSION 2010 Conference & Expo. A copy of the paper can be obtained direct from NACE International.

PREN, G48 & CPT Testing
Various corrosion related tests and calculations including PREN, G48 and CPT can be applied to stainless steel and related nickel and chromium based alloys, but none of these tests are appropriate for Tungum as it is a copper based alloy.

PREN Pitting Resistance Equivalent Number. NACE and NORSOK typically require a PREN of 40 minimum for oil and gas applications. Normally calculated using the formula: $PREN = wt\%Cr + 3.3wt\%Mo + 16wt\%N$. This formula, however, cannot be applied to Tungum because it is a unique copper based alloy and does not contain any Molybdenum or Chromium.

ASTM G48 Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys. By definition this standard does not apply to copper based alloys.

CPT Critical Pitting Temperature for Stainless Steels and Related Alloys. This can be determined either by ASTM G48 method C or E. Alternatively, using electrochemical test methods to ASTM G150 Standard Test Method for Electrochemical Critical Pitting Temperature Testing of Stainless Steels. Again, by definition these standards do not apply to copper based alloys.

NACE Corrosion Testing in Marine Applications

Tungum corrosion testing results can be found in various articles including:

- NACE Paper No. 10305** entitled '316 Stainless Steel Instrument Tubing in Marine Applications – Localized Corrosion Problems and Solutions.'



CONSIDERATION SHOULD BE GIVEN TO THE USE OF TUNGUM TUBING IN LOCATIONS WHERE TUBING REPLACEMENT IS DIFFICULT AND LONG TERM USE WITHOUT MAINTENANCE IS REQUIRED.

Jim Lawrence, Principle Engineer Control Systems & Instrumentation at Mustang Engineering.





DESIGN AND INSTALLATION

Introduction

Advice:

Calculating Tube Wall Thickness

Cutting and Bending

Silver Soldering and Brazing

INTRODUCTION

A straightforward material to deal with

Tungum's special combination of high strength and ductility render it one of the easier materials to use on even the most complex system.

The purpose of this section is to show users that Tungum Tubing is a straightforward and trouble-free material to deal with, provided that good engineering principles and best working practice are used. It also emphasises that where other materials and manufacturers' parts are used, the appropriate instructions supplied with them should be followed. We have attempted to cover the most common situations likely to be encountered. In the event of any problems arising, we are always available to advise on specific matters.



NOTES ON INSTALLING TUNGUM TUBING PIPEWORK

- + Select the appropriate wall section for the pressure and service.
- + Design pipe runs to allow access and easy removal of important equipment.
- + Provide adequate and correctly placed supports; to ensure vibration is controlled to an acceptable level.
- + Select clamps which are 'kind' to the tube surface, but which grip it tightly.
- + Produce generous bends using the same radius throughout. Always allow adequate room for clamping between bends.
- + Ensure each pipe fits correctly without imposing additional loads on couplings/pipe joints.
- + Protect small diameter pipe runs against being used as ladders or hand holds.



PLEASE NOTE: TUNGUM TUBING SHOULD NOT BE USED IN THE PRESENCE OF ACETYLENE, AMMONIA OR MERCURY



Design and Installation:

CALCULATING TUBE WALL THICKNESS

A number of formulae can be employed for calculating the wall thickness of tubes to withstand internal pressure.

See our website for a pressure calculator using the ASME B3.1 calculation.

WWW.TUNGUM.COM

Clamping

Design a clamping arrangement into the system which will not crush, flatten or allow vibration to wear away the tube at the clamp.

Layout and shielding

Tube runs should have adequate protection against accidental damage. Tubing should never be a stressed component in a structure. Oxygen lines should not be routed near hydraulic equipment or flammable substances.



Recommended Clamping Distances

Tube O/D Size	Inches	1/8 – 5/16	3/8 – 3/4	1 – 2
	mm	3 – 8	10 – 20	25 – 50
Clamping Distance	Inches	20 – 30	30 – 45	45 – 70
	mm	500 – 750	750 – 1150	1150 – 1800

Design and Installation:

CUTTING AND BENDING

We recommend that you use a saw, not a 'Tube cutter' and make sure the end is cut square to the tube axis, after cutting, de-burr the tube internally and externally, and make sure all swarf is removed.

The Planning of Tube Bends

It is conventional to refer to the centre line radius (CLR), which is the radius of bend to the centre line of the tube. This radius is expressed as a multiple of the tube outside diameter (O/D). For ease of working, and to reduce turbulence, the radius should be as large as possible. Bends with a CLR of less than 3D should be avoided where possible.

Ovality

A round section tends to become oval during bending. Ovality on bends significantly reduces the fatigue life and effective bore size of a tube and should be controlled to acceptable limits, approx. 5% maximum. Ovality can be reduced to a minimum by the correct use of mandrels during bending.

Thinning of Bends

The other effect of bending a tube is to reduce the thickness of the wall on the outside of the bend. This effect should be allowed for when initially choosing the thickness of the tube to be used.

In general, some end users employ a factor of '1.13 x the selected tube wall' to cover thinning on bends having 3D radius or greater.

Spacing of Bends

Avoid compound bends. Sufficient space for clamping should be allowed between bends.

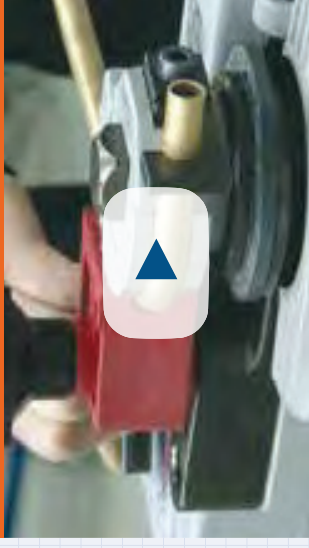
The effect of Bending near the end of the tube

Bends near the end of the tube will tend to draw the face of the tube out of square. Sufficient length must be left so that the tube can be cut square.

CUTTING TUNGUM TUBING



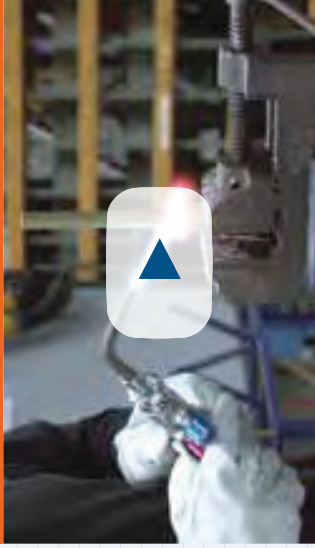
BENDING TUNGUM TUBING



www.tungum.co.uk/technical-zone/how-to-videos



BRAZING TUNGUM TUBING



www.tungum.co.uk/technical-zone/how-to-videos



Design and Installation:

SILVER SOLDERING AND BRAZING

Silver soldering and brazing are reliable methods of joining Tungum Tubing together but does require some specific technical knowledge and practical ability to successfully make joints.

The main points to be considered are:

Clearances: Between mating parts: These are the responsibility of the designer.

Cleanliness: In making joints in any metals, the parts must be clean, free from grease and oil and with all burrs removed.

Temperature: The optimum temperature is 650°C/700°C which should be applied for as short a time as it is necessary to make a good joint. The temperature may be judged roughly when the metal shows dull red. For more accuracy, thermally sensitive crayons may be used.

If Tungum Tubing has been overheated, or the heat applied for an abnormally long period of time, it may result in some reduction in strength of the material.

Methods of Brazing

Thoroughly clean and de-burr the end of the tube and the fitting and remove all debris. Mix to a thick paste 'Easyflo'

(or equivalent) powder and water, or use a ready-mixed flux paste, applying it to the outside of the tube and the inside of the fitting. Using a solder wire or a ring of appropriate size and thickness in the fitting (1.5 mm). Fit the fitting to the tube and, if possible, rotate it to distribute the flux evenly. Apply heat by moving the flame round and heat the mass of the fitting rather than the tube. As soon as the solder has melted, press the fitting onto the tube, ensuring that it makes contact with the step, and rotate it to spread the solder evenly. At this stage, a witness of solder should appear, then remove the flame. If it appears that there is insufficient solder, reheat and apply more. As soon as possible after brazing, the flux should be cleaned off. This may be done with hot water and a wire brush. A good finished joint will show a witness of solder in a complete circle, on the end of the tube, inside the fitting and round the end of the fitting outside the tube.



I HAVE BEEN WORKING IN DRASS SINCE 2006 AND FROM THE FIRST DAY I HAVE USED TUNGUM PIPES IN MY PROJECTS. THE CHARACTERISTICS OF TUNGUM PIPES PERMIT AN EASY BENDING AND INSTALLATION INSIDE THE GAS PANELS AND THE DIVING BELLS. DRASS USES TUNGUM FOR ALL OXYGEN AND MIX GAS LINES OF THE DIVING SYSTEM (AIR DIVE AND SATURATION).

IN THIS MOMENT, 7 DRASS DIVING SYSTEMS ARE WORKING AND OTHER 6 SYSTEMS ARE IN PROGRESS AND IN THE PAST 10 YEARS I HAVE NO RECORDED FAILURES IN TUNGUM PIPES.

TUNGUM PIPES ARE PERFECT FOR AN INSTALLATION WITH TWO-FERRULE OR FLARE (SAE J514) FITTINGS.

I RECOMMEND TRYING OUT THESE PIPES, YOU'LL THANK ME!

Dino Tempesti, Snr Mechanical Engineer and Piping Expert at DRASS.

