

★ **Tailored to you
the customer**

*The methods behind
CRYOSTAR know-how*



★ **Who you gona call?**

*Improving and extending
customer services*

★ **MAGMA hits ethylene market**

*Turbo expanders are hot on control
and flexibility*



Customer service is the very life-blood of CRYOSTAR. It encompasses everything from before to after-sales service. Above all it reflects CRYOSTAR's determination to work with customers, delivering what they want when they want it, to the highest international standards.

One aspect of CRYOSTAR customer service is the technological innovations behind our products. In every market, in all geographies, CRYOSTAR technology provides our customers with a competitive edge.

CRYOSTAR is at the forefront of cryogenic technology – more than 40 years studying the art of cryogenics has led to a multitude of innovative solutions, new applications and technological improvements.

Be it pumps, automation, turbines, expanders or LNG shipboard equipment, CRYOSTAR continues to invest in research and development. Never a day goes by without our engineers pushing the boundaries in one field or another.

In recent times we have brought to the market the MTC; the GBSD transport pump range; the Modular Reciprocating Pump; the power recovery turbine; turnkey LNG / biogas installations; fuelling and filling stations; hydrogen related cryogenic equipment... and the list goes on.

In this edition of CRYOSTAR magazine we continue to highlight the latest advances in technology and in Tailored to you, the customer, page 3, we provide some insight into how our business operates.

At CRYOSTAR we believe in innovation, service, research and development, working in partnership with customers. In the many markets in which our customers operate, competition is keen and demands are constantly changing.

CRYOSTAR recognises this, which is why we put so much effort into improving technology, improving our service offerings. It's what makes CRYOSTAR a market leader.

We are committed to the pursuit of innovative technology, committed to meeting our customers' needs, any time, any place. CRYOSTAR technology is the jewel in many a customer crown and we're proud of that.


Daniel MEYER
President



- ★ Tailored to you, the customer p 3
- ★ Cryostar gets its MAGMA turbo expanders in ethylene market p 5
- ★ Everyone's a winner with us p 7
- ★ Controlling the process p 8
- ★ News p 9
- ★ Who you gonna call? p 10
- ★ Events p 11
- ★ Tools and datas p 11



Tailored to you, the customer



Thousands of engineering solutions for hundreds of companies – Cryostar know-how, a jewel in many a customer's crown...

Four hundred different centrifugal and reciprocating cryogenic pump models, more than fifty different turbo machine frame sizes and thousands of precisely engineered designs – all to meet the needs of the cryogenic and atmospheric and hydrocarbon gases industries. For 40 years Cryostar has been developing custom-made, designed and engineered products and machinery.

But what is that makes Cryostar tick? Well, there is the 'developments' side, which can be split into three major platforms: machinery, applications and process. Machinery is driven by individual customer and general market demand, and is based on existing machines and Cryostar expertise. Applications are derived from working closely with customers to help them further exploit Cryostar products.

Process, on the other hand, is very much internal, with Cryostar research and development engineers working with frontline staff to ensure the delivery of products to exacting international standards. This way the best process and most efficient machine can be developed for the market and customer fast.

However, 'developments' can also be categorised as 'on the job' and 'off the job'. 'On the job' is usually reserved for those large machines, which are extensions of the Cryostar product portfolio. 'Off the job' is predominantly for products later sold in quantity, like small cryogenic pumps or turbines, usually developed without a specific order but with an eye on future customer needs.

Development cycles

Products that come under 'on the job' are developed and built during the normal contract and commercial cycle, and delivery times are dictated by the competitive situation.

During such developments, which are usually done by Cryostar engineers, there are extensive design reviews and additional calculation cycles with the possible inclusion external consultants. An extensive in-house testing period follows completion. Importantly, the customer can also be involved in the assessment cycle. This is because design validation testing must fulfil predetermined test criteria to gain customer sign-off. Cryostar's inherent attention to detail also means its development engineers are involved in the commissioning and start up of a new machine.



In case of the 'off the job' developments, the design and production will undergo same cycles, but without the customer involvement and typically without any major time constraints. More important is the extensive and long-term in-house testing of a new product, to demonstrate suitability and performance levels to the market. The new product is launched only if the extensive testing shows it fulfils or supersedes expectations. In many cases this also includes extended testing at selected customer sites prior making it generally available.

The test tools

As well as development validation Cryostar also has performance testing capabilities. In Hésingue, the company has two large test facilities, one for cryogenic pumps and the other for turbo machines. In Capdenac, Cryostar Automation test facility allows for complete filling stations and control systems to be fully tested. All are equipped with automated data acquisition systems.

The test facility for pumps includes two liquid nitrogen vacuum insulated cryogenic tanks with five different metering test lines. Reciprocating pumps up to 600 bars and 100 l/min, and centrifugal pumps for up to 100 bars at flows up to 14'000 l/min, can be tested using liquid nitrogen. This cryogenic test facility is the largest of its kind for industrial gases pumps in the world.

The turbo machines test facility has a test space for simultaneous preparation and sequential testing of four low-duty compressors and for four high-duty compressors for LNG carriers (two ship sets) at 60 Hz and any voltage up to 6'600 Volts. The third set of compressors can be under preparation, while the forth can be at the completion stage after the testing.

In addition, up to six turbo expanders can be located in the test hall for testing with pressurized air. The today's volumes are in the order of 160 LNG carriers' shipboard compressors and around 100 turbo expanders per year. This can be extended

easily by staff working in tailored shift patterns.

People and Expertise

And that is why the backbone of Cryostar is its staff of almost 300. There are engineers with bachelor, master or even higher (PhD) degrees. Through internal training courses and know-how transfer from more experienced colleagues Cryostar continues to strengthen its capabilities. Staff development is a priority and Cryostar invests close to three per cent of its annual turn over in training with a larger part dedicated to engineering and development staff.

This type of investment in people allows Cryostar to tackle and deliver solutions to varied and often complex customer problems. Not only does it have extensive cryogenic know-how and aerodynamic and hydraulic design expertise to call on, but 35 years in this specialist market has armed the company with expertise in many other areas.

They include: materials at cryogenic temperatures, stress analysis, heat transfer, cryogenic vaporisation and condensation together with other unit operations, oxygen compatibility of materials, and pressure containment design for extreme pressures.

Coupled with these are a multitude of specialist tools, including: CAD for the design of turbo machines and pumps; CFD software for flow and pressure distribution analysis in turbo machines and pumps; and FEA software for wheel blades resonance and for stress and displacement calculations, to name but a few.

For very specific tasks like rotor dynamics and rotor vibration behavior, aerodynamics and hydraulic design and analysis, external consultants can be brought in for independent evaluations.

All these disciplines combine to form the basis of Cryostar's technological and commercial success. In other words, it's what makes the company tick.

The technological testing during the production cycle (hydro testing, gas leak testing, balancing, over speed testing, holographic blade resonance testing, etc.) will be the subject of a future article.

Cryostar gets its MAGMA turbo expanders in ethylene market

For ethylene plant owners, Cryostar has designed and built a dual turbo expander compressor (2-MTC) solution that provides safety, ease of control and flexibility.

Both low pressure (LP) and high pressure (HP) units are mounted on the same skid, with explosion-proof instruments. The units are equipped with active magnetic bearings and controlled through a Cryostar-programmed Programmable Logic Controller.

Two expanders in series expand the off-gas fluid, with braking power being provided by compressor wheels mounted on the same shaft. Both units rotate at the same high speed to maximise the expanders' efficiency.

Magnetic bearings provide a 100 per cent leak-safe design, avoiding any risk of oil ingestion into the process gas. Both LP and HP expanders can be independently by-passed by the process gas. Therefore, either the LP or the HP machine can be operated as a single unit. This feature enhances process flexibility.

At the root of this achievement is a state-of-the-art design process for wheels and shafts. The gas to be expanded combines a low molecular weight (less than 5 kg/kmol) and a high massflow (more than 1000 kmol/hr). The low molecular weight requires extremely high tip speed of the wheels for optimum efficiency.

For a price-competitive solution, Cryostar opted for two machines belonging to the MTC200 frame size. MTC200 are magnetic bearings turbines braked by a compressor wheel, with an expander wheel diameter of nominally 200mm. For both HP and LP machines, the expander wheel is made of a high strength aluminium alloy and the diameter is 210mm. Compressor wheels are made of the same material with a 220mm diameter. All are milled from solid. This straightforward design solution as described below eliminates any risk of wheel cracking by blade resonances.

High speed rotor development

Prior to rotordynamics investigations, the natural resonance of the wheels must be calculated. The modal analysis of expanders and compressor wheels showed no risk of resonance in the range of operating speeds. This assessment was performed using Finite Element Analysis (FEA). Once optimised, geometries of the wheels were fed into models representing full rotors, to be used for the rotordynamics analysis.

Due to the high maximum continuous rotating speed close to 40,000 rpm, and the relatively large wheels for MTC200 machine frame size, the new rotor design was a challenge that Cryostar experts were eager to face. Actually, with respect to the lateral critical speed analysis (LCSA), several iterations were needed to meet the API acceptance criteria.



The LCSA aims to defining rotor natural frequencies associated with structural deflections of the rotor. Natural frequencies are converted into rotating speed values called critical speeds.

All structures possess natural frequencies at which they vibrate most violently when struck. For a rotor, a state of resonance can be reached if the rotation frequency equals one of the rotor natural frequencies. This phenomenon leads to deformations, which can severely damage the structure.

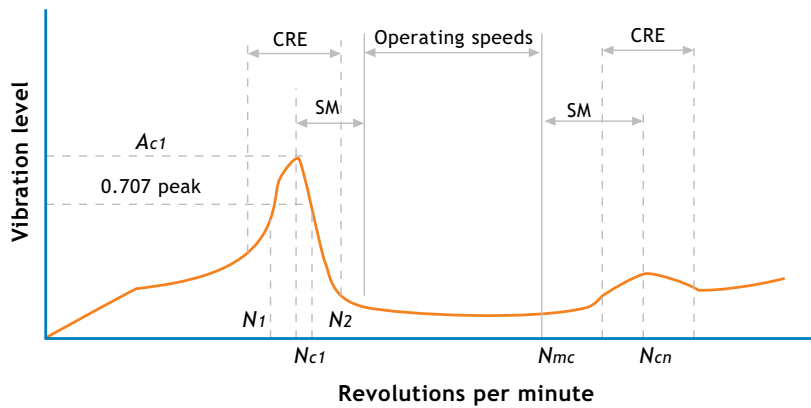
With regard to LCSA, API 617 standards require that either the deflection of the structure is low enough or that the difference between the maximum continuous speed and the first critical speed is high enough (see “Technical data panel for accurate criteria”).

The LCSA enabled Cryostar to find the appropriate rotor for a resonance-free design. Iterative refinements of detailed design features were carried out in close co-operation with S2M, the magnetic bearing supplier. API acceptance criteria were met with a remaining safety margin.

High-tech design methods, combined with pragmatic targets, resulted in a smart and robust solution.

*The first two-stage Cryostar MAGMA turbo expander 2-MTC of this high speed configuration was designed and built for cold production in a new ethylene plant in Qatar.

Technical data



The amount of expected deflection of the rotor is quantified by API standards with the amplification factor AF (The higher the Amplification Factor, the sharper the deflection peak):

$$AF = \frac{N_{c1}}{N_1 - N_2}$$

N_{c1} : Critical speed corresponding to the maximum deflection
 N_1 and N_2 : Lesser and greater speeds at 0.707 x peak deflection (The peak deflection is at critical speed N_{c1})

The difference between the maximum continuous speed and the first critical speed is quantified by API standards with the separation margin SM, defined as follows when the critical speed is greater than the maximum continuous speed:

$$SM = 100 \times \frac{(N_{c1} - N_{mc})}{N_{mc}}$$

N_{mc} : Maximum continuous speed

Depending on the AF value, the API 617 standards acceptance criteria is:

1. If $AF < 2.5$, no SM is required

2. If, $AF \geq 2.5$, $SM > \text{Min} \left\{ 26; \left[10 + 17 \times \left(1 - \frac{1}{AF - 1.5} \right) \right] \right\}$

in case of a critical speed higher than the maximum continuous speed.

3. If, $AF \geq 2.5$, $SM > \text{Min} \left\{ 16; \left[17 \times \left(1 - \frac{1}{AF - 1.5} \right) \right] \right\}$

in case of a critical speed lower than the minimum speed (not applicable to the developed case).

Everyone's a winner with us

Mahmood Javed, R&D Manager at Abdullah Hashim Gas in Saudi Arabia, visited the Cryostar headquarters in Héringue, France on 29 April with his wife, as part of his prize for winning the Cryostar Middle East Competition in February this year.

His visit began with the presentation of a souvenir Cryostar photo album along with a few words of congratulations from Daniel Meyer, Cryostar's President. This was followed by a slide show on the company and a tour of the site with Philippe Fauvel, Sales Manager, South Europe and the Middle East.

The tour started in the main administration building which contains sales, purchasing and central management for the company. Although based in France, the headquarters is on the borders of both Germany and Switzerland, an important factor for a company which exports around 90 per cent of its products. "Even our employee base is multinational," said Philippe. "We have over 230 people from 12 countries working at our French headquarters alone."

The tour also took in Cryostar's research and development offices. "We have a team dedicated to R&D," explained Frédéric Marcuccilli, R&D engineer. "And it is thanks to this team that we are able to develop and customise solutions to exact needs of individual customers."

At the assembly workshop, our winner was able to see first hand the construction of several product lines from the large LNG compressors to the vast range of world-leading Cryostar cryogenic pumps.

"Mahmood was very impressed with the high quality of Cryostar production tools and the commitment shown of all employees. Customer satisfaction is something we all focus on," said Philippe.

At a cost of over 4 million Euros, Cryostar's testing facilities represents a huge customer service investment. "We have the world's most sophisticated test stand for pumps," said Laurent Rapp, test stand manager, "Not only has it helped to expand our R&D programme but we also provide individual customised test reports. One hundred per cent of the material our customers buy is tested before delivery."

Final stop on the tour was the on-site maintenance shop and customer service department.

Our winner expressed his hopes that the visit would be the start of a strong relationship between the two companies.

The winner's weekend continued with sight seeing trips around the region including Colmar, in Alsace, France, and the Black Forest in Germany.

The Middle East Competition was a great success with triple the industry average in responses. It is hoped that the programme can now be expanded to other regions.



Controlling the process

To meet rising customer expectation in the fast changing Programmable Logic Controller (PLC) world, Cryostar makes use of cutting edge solutions...

The escalating plant sizes are putting tremendous pressure on reliability and availability requirements to avoid any downtime or production loss. In addition, to reduce installation costs, less manpower is available on site, so reducing the manual activity to a minimum requires increased use of process automation.

Since the beginning of the process industry, control systems have been required to meet ever-changing demands. So over the last few years, Cryostar has implemented many different PLC configurations to suit specific customer needs. The latest main developments are:

Redundancy

In order to deal with increased demand on availability, PLC redundancy is implemented. It avoids disruption of the process in case of machine PLC failure. Different redundant configurations are possible. As a minimum, the power supply and the CPU are duplicated, where the second unit takes over the duty instantaneously in case the first fails, ensuring continuous machine operation.

A further extension of redundancy can be the duplication of the inputs and outputs (e.g. an analogue 4-20mA output signal is fed a half-signal by each of two output modules, and full-signal by one module in case the other fails). Detected instrument failures, resulting in the shutdown of machinery, also leads to a reduction in overall plant reliability and availability. So spurious 'trips' have to be avoided. This is done by triplication of selected sensors and by the implementation of a two-out-of-three voting (2oo3) so at least two sensors must detect the faulty situation in order to initiate a shutdown and the process continues in case of failure of a single sensor.

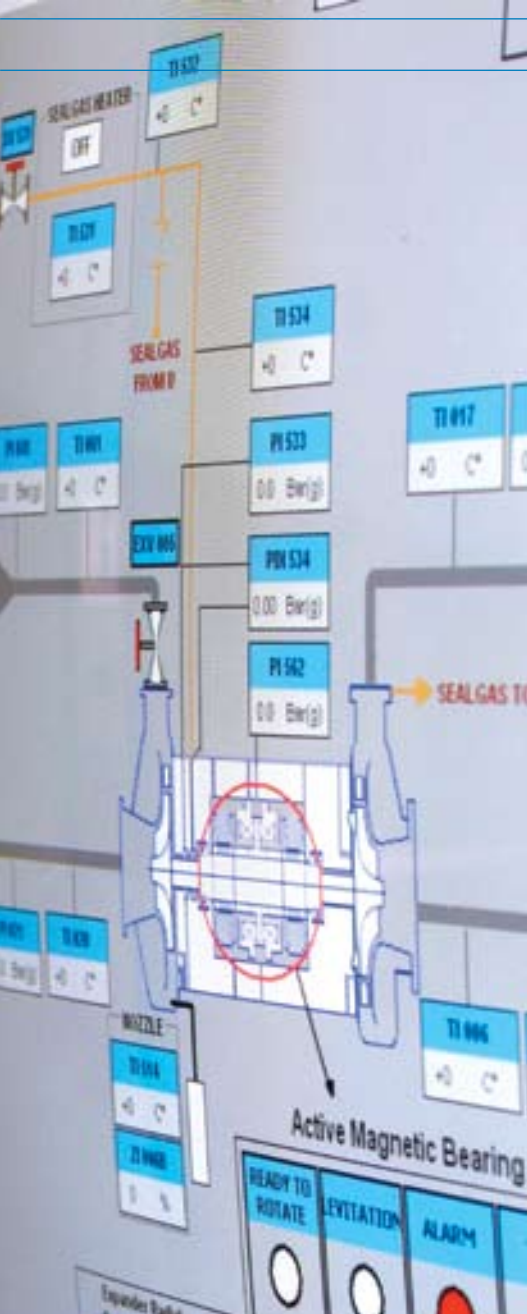
Safety

Safety systems have traditionally required hard wiring and the use of electro-mechanical components. Today, except for specific safety functions like the emergency shutdown, dedicated 'Safety PLCs' have

started to replace the other safety related hard-wired circuits.

As state-of-the-art technology sets the trend towards application of best in class PLCs and as safety of people and environmental protection become more important, customers will reject lower integrity systems. This, together with the likelihood that safety integrated level requirements might be needed in the future, drives the use of the safety PLC.





Remote I/O

To reduce site installation costs, PLC remote input/output (remote I/O) technology has been developed. This is where multiple hard-wired cables are replaced by a single or a redundant communication link. This technology has been around for some time, and since it is now field proven, its popularity has increased. It is now also certified for hazardous areas, even for Zone I (on shipboard applications the remote input/output is becoming standard equipment).

Interfaces

Data exchange with the different plant central controls, emergency shutdown or machine maintenance systems are done by serial communication links, with Modbus the preferred protocol.

Flat panel displays with touch-screens are forcing the traditional lamp and push-button machine interfaces into the history books. The colour displays, showing machine mimics, on-line machine performance and operating conditions, are much more user friendly and able to provide more information.

In conclusion, whether installed in hydrocarbon or industrial gas plants, Cryostar's equipment is critical for plant operation. The availability requirement for this equipment remains high and customer expectations continue to rise. This applies, of course, to both the mechanical components and the control system, which is why Cryostar is at the cutting edge of technological changes and trends offering state-of-the-art solutions to fulfil customers' growing requirements.

News

Biggest turbo expanders ever built by Cryostar

The biggest turbo expanders ever built by Cryostar - 2 MTC 600/240 for the Orman Lange (Norway) project - were successfully tested and shipped in September. The main characteristics of these huge machines are:

- MTC 600/240 frame size going up to 12 MW
- Largest magnetic bearings for high speed applications with diameter 240 mm
- Compressor housing diameter 1600 mm and 100 bar design pressure.

In testing the machines the following were used: six oil free screw compressors, diesel motor driven, with total 2,375 kW power and 16,000 m³/hr throughput in addition to the installed PGW 4 stage centrifugal compressor with 1250 kW electric motor and 11,000 m³/hr.

Exhibition in China

Cryostar attended the IG China exhibition in Hangzhou in September. A team from our Hangzhou office and a delegation of the Cryostar SAS (France) management team attended to present Cryostar and its solutions to the Chinese market. The response was excellent and many Chinese customers took the opportunity to discuss current and future projects.

Cryostar USA East is moving

We are pleased to announce that in order to meet growing demand in the US, Cryostar USA PA will move to a larger facility in Allenton, PA. The new facility enjoys a total of 750 square metres of shopfloor and office space. The new address is:

5897 Colony Drive
Bethlehem, PA 18017
USA



Who you gonna call?

Cryostar's Customer Service Department (CSD) is dedicated to achieving and even surpassing the highest standards of service expected by all customers. "We are continually looking to improve and extend the services we provide," said Didier Walch, Customer Service Director. "At Cryostar we want to grow our customer partnerships and develop in unison with the customer, to realise an enduring and mutually productive future together."

The CSD, based at the company headquarters in France, is currently staffed by more than 40 market and product service specialists, all dedicated to ensuring efficient, and customer focussed, before, during and after sales service.

In fact, this central team manages all customer service activity around the world. The team develops all Cryostar standards, which are then duplicated across the company's network of business centres and local agents, ensuring consistently high quality service on all five continents.

But the network is not just a day-to-day support mechanism for customers, it represents a powerful combination of local solution providers able to tap into an international pool of experience and expertise.

"Every Cryostar business centre maintains a 24-hour emergency telephone service and our engineers are available for call out at any time," said Julien Rivello, Customer Service Operations Manager.

Product reliability

Cryostar understands the importance to customers of product reliability. As a result, dedicated maintenance shops and maintenance teams are based in France, the UK, China and the US. Expert support is equally available in other regions

for start-ups, consulting, commissioning and on-site maintenance and audits.

OEM guaranteed high quality parts, fully comprehensive parts kits, management of spare and wear parts and scheduled or emergency delivery times are another of the cornerstones on which Cryostar's network meets the needs of customers. And so is the web-based spare parts supply portal which will soon be on-line, allowing contracted customers to order spares, check pricing and receive delivery confirmation.

Adding value is another Cryostar cornerstone. The CSD does this by providing efficiency and/or lifetime improvements and retrofit upgrades of existing machines, often increasing running hours and creating important savings for our customers. Another aspect is fully customised training sessions for all Cryostar products and applications, using all the latest tools and technologies for learning.

"Years of experience and expertise in the industry enables Cryostar to take on the full service element for the customer," said Marc Runser, Applications and Customer Service Manager, Distribution products and services.

"We can provide individual, innovative service agreements, customised to particular requirements, with a focus on providing peace of mind for the customer.

"Cryostar maintenance agreements can include anything and everything, from the basic preventive maintenance of pumps and turbines, through to consulting, training, crane hire and repainting."

Cryostar's Customer Service Department is all about customer care – so if you have a problem you know who to call.

Events

★ November, 2005

Oil & Gas Exhibition 2005, Fiera Milano, Padiglioni 14, 15, 16, 20145, Milano, Italy

★ November, 2005

IPPEX 2005, Nippon Convention Center, Nakase 2-1, Mihama-ku, Chiba City, 261-0023, Japan

★ February, 2006

SOPEC 2006, Dhahran International Exhibition Centre, P.O.BOX 7519, Dammam 31472, Saudi Arabia

★ April, 25-29, 2006

Welding Zagreb, Zagreb Fair, Avenija Dubrovnik 15, HR-10020 Zagreb, Croatia

★ May, 23-26, 2006

SVARKA - WELDING 2006, Lenexpo Fairgrounds, 103 Bolshoy Prospect; St. Petersburg, 199106, Russia



Tools and datas:

Combustion constants of Hydrocarbon Gases

Name of gas	Symbol	Mol Weight	Heat of Combustion		Pound per Pound of Combustible Gas					
			Gross	Net	Required for Combustion			Products of Combustion		
					BTU per Pound	O ₂ +	N ₂ =	Air	CO ₂	H ₂ P
Carbon (Solid)	C	12.011	14,093	14,093	2.664	8.863	11.527	3.664	-	8.863
Hydrogen	H ₂	2.016	61,100	51,623	7.937	26.407	34.344	-	8.937	26.407
Carbon Monoxide	CO	28.010	4347	4347	0.571	1.900	2.471	1.571	-	1.900
Methane	CH ₄	16.043	23,879	21,520	3.990	12.257	17.265	2.744	2.246	13.275
Ethane	C ₂ H ₆	30.070	22,320	20,432	3.725	12.394	16.119	2.927	1.798	12.394
Propane	C ₃ H ₈	44.097	21,661	19,994	3.629	12.074	15.703	2.994	1.634	12.074
Ethylene	C ₂ H ₄	28.054	21,644	20,295	3.422	11.385	14.807	3.138	1.285	11.385
Propylene	C ₃ H ₆	42.081	21,041	19,691	3.422	11.385	14.807	3.138	1.285	11.385
Acetylene	C ₂ H ₂	26.038	21,500	20,776	3.073	10.224	13.297	3.381	0.692	10.224



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