Contributions to the CEC/ICMC '95
July 17 - 21, 1995 in Columbus, Ohio
TECHNICAL CHALLENGES OF SUPERCONDUCTIVITY
AND CRYOGENICS IN PURSUING TESLA-TTF

Quan-Sheng Shu for the TESLA Collaboration
Deutsches Elektronen-Synchrotron (DESY)
Notkestrasse 85, 22607 Hamburg, Germany

ABSTRACT

TESLA (TeV Energy Superconducting Linear Accelerator) Collaboration is an international R & D effort towards the development of an e+e− linear collider with 500 GeV center of mass by means of 20 km active superconducting accelerating structures at a frequency of 1.3 GHz. The ultimate challenges faced by the TESLA project are (1) to raise operational accelerating gradients to 25 MV/m from current world level of 5-10 MV/m, and (2) to reduce construction costs (cryomodules, klystrons, etc.) down to $2K/MV from now about $40K/MV.

The TESLA Collaboration is building a prototype TESLA test facility (TTF) of a 500 MeV superconducting linear accelerator to establish the technical basis. TTF is presently under construction and will be commissioned at DESY in 1997, through the joint efforts of 24 laboratories from 8 countries. Significant progress has been made in reaching the high accelerating gradient of 25 MV/m in superconducting cavities, developing cryomodules and constructing TTF infrastructure, etc. This paper will briefly discuss the challenges being faced and review the progress achieved in the technical area of superconductivity and cryogenics by the TESLA Collaboration.

INTRODUCTION

There is a widespread consensus within the high energy physics community that the next electron positron collider would be built with a center of mass energy of 500 GeV and luminosity of a few times $10^{33}$ cm$^{-2}$s$^{-1}$. Such a collider would provide for top analyses and also have the potential for discovery such as Higgs mass below = 350 GeV. Worldwide, there are a number of groups pursuing different linear collider designs. The TESLA collaboration is an international R & D effort to develop a linear collider using superconducting accelerating structures (25 MV/m, $Q_0=5x10^9$) at low frequency (1.3 GHz)\textsuperscript{1,2,3}. The TESLA collaboration consists of 24 institutes from 8 countries.

Advantages of TESLA

The technical advantages of superconducting RF cavities is their high Q value and low RF wall losses (less than Cu cavities by a factor of $10^5$). It allows us to use large aperture structures operating at low frequency (1.3 GHz, L-band) with long macro pulse length and low peak power requirements. The large aperture has a beneficial consequence of
substantially reducing transverse and longitudinal wake field effects, leading to relaxed Linac alignment and tolerances.

Challenges of TESLA

Despite the attractive feature of the TESLA design, a major effort is needed to demonstrate that a linear collider can be built at a cost competitive with its normal conducting counterparts. The two technical challenges being faced and the key approaches to reach the ultimate goals can be summarised as follows:4,5

1. Increase operational accelerating gradients of SRF cavities to 25 MV/m from current levels of 5-10 MV/m by eliminating field emission and thermal breakdown.
2. Decrease structure cost by utilising multicell structure, long cryostat, high efficiency klystron and cost effective fabrication techniques.

With the above efforts, we believe that the construction cost can be reduce to $2K/MV compared to the current $40/MV. The TESLA Collaboration is building a test facility (TTF) of a 500 MeV superconducting linear accelerator (~90-m length) to establish the technical base.

BASIC INFORMATION ABOUT TESLA AND TTF

TESLA Layout

The overall layout of the TESLA 500 is illustrated in Figure. 1.1,6 The electron beams (e+ & e−) are accelerated to 250 MeV by RF fields in each main linac. Each linac has an active accelerating length of 10,000 m consisting of about 10,000 superconducting RF cavities. Total length of TESLA-500 is about 32 km. A discussion of the layout is introduced in the reference.6 An overview of the main parameters of TESLA-500 is given in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linac energy</td>
<td>2x250 GeV</td>
</tr>
<tr>
<td>Beam pulse current</td>
<td>8 mA</td>
</tr>
<tr>
<td>Number e/bunch</td>
<td>3.63 x 10^10</td>
</tr>
<tr>
<td>Nu. of bunches/pulse</td>
<td>1130</td>
</tr>
<tr>
<td>RF pulse length</td>
<td>1.3 ms</td>
</tr>
<tr>
<td>Beam pulse length</td>
<td>0.8 ms</td>
</tr>
<tr>
<td>Luminosity</td>
<td>6 x 10^33 cm^2 s^-1</td>
</tr>
<tr>
<td>Bunch separation</td>
<td>0.7 μs</td>
</tr>
<tr>
<td>Bunch length</td>
<td>0.7 mm</td>
</tr>
<tr>
<td>Rep rate</td>
<td>5 Hz</td>
</tr>
<tr>
<td>Total Length (incl. inter. reg.)</td>
<td>32 km</td>
</tr>
<tr>
<td>RF Freq.</td>
<td>1.3 GHz</td>
</tr>
</tbody>
</table>

As shown Figure 1, TESLA is composed of many components. However, we only introduced the technical issues relevant to low temperature sciences here. For convenience of discussion, we consider the TESLA-500 as a superconducting and cryogenic structure which is energized through thousands of high power RF couplers and cooled by a huge superfluid-He refrigeration system. Therefore, the structure of the 20-kilometer active accelerating machines can be simplified and summarised as in Table 2 with a SRF cavity.
Table 2. TESLA-500 as a superconducting and cryogenic machine
(consider SRF cavity as basic unit)

<table>
<thead>
<tr>
<th>9 SRF cavity cells</th>
<th>A cavity (including LHe vessel, RF couplers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 cavities, etc.</td>
<td>A cryomodule of 12.2 m, and</td>
</tr>
<tr>
<td></td>
<td>4 cryomodule share one 10 MW klystron</td>
</tr>
<tr>
<td>12 cryomodules (incl quadr packages)</td>
<td>A string of 148 m, has an individual cryo-loop</td>
</tr>
<tr>
<td>12 strings</td>
<td>A TESLA subunit of 1830 m</td>
</tr>
<tr>
<td>16 subunits</td>
<td>one subunit has a 3.2 kW 2K cryo-plant</td>
</tr>
<tr>
<td></td>
<td>The TESLA-500, with active superconducting</td>
</tr>
<tr>
<td></td>
<td>accelerating length of 20.000 m</td>
</tr>
</tbody>
</table>

(Eacc = 25 MV/m, Qo = 5x10^9) as the smallest unit. The basic cryogenic structure unit is a cryomodule consisting mainly of 8 cavities. 4 cryomodules share a klystron of 10 MW peak power. The heat load to 2K from a cryomodule is 21.4W including dynamic (RF) and static losses 7. To keep the TESLA machine in superconducting state, the total cooling power estimated is: 50.6 kW at 2K, 36.9 kW at 4.5K and 314 kW at 40/80 K 8. Sixteen 2K-refrigerators are needed to provide the cooling power distributed over a 30km-length. The total liquid He inventory estimated in the TESLA machine is about 87,200 - 102,800 kg (respectively to different versions of cooling loops).

TTF Layout

Figure 2 is a schematic layout of the TTF consisting of an injector with RF gun and capture cavity, 15 MeV beam analysis area, TTF Linac (50m) with four cryomodules including 32 SRF cavities (with Eacc=15 MV/m and Q=3x10^9 as the design goal) and 4 SC quadrupole focusing magnets and a high energy experimental area. The TTF is refrigerated by a He II refrigerator: 100 (200)W/1.8K, 400W/4.5K and 2000W/70K.

With the TTF, we will demonstrate and verify many technical issues, such as, cavity processing technologies, cavities performance, design of couplers and cryostat, cryogenic operation, energy and position feedback, alignment, etc.

The TTF is also being considered for use as a Free Electron Laser Facility.

TESLA SRF CAVITIES

The TESLA SRF cavity is shown in Figure 3 and an overview of the main parameters is given in table 3. The TESLA cavities are made of high purity Nb sheets (2.8 mm) with a RRR of about 300. The cavity shape combining an elliptical iris and a spherical equator results in more satisfactory electromagnetic parameters than other combinations. Another consideration to TESLA cavity design is to minimize the ratio both of Epeak/Eacc (2.1) and Hpeak/Eacc (4.2, mT/MV/m) in order to reach highest gradients 3,7. The maximum cell number of 9 is determined by effective HOM damping requirement. There is one input power coupler and two HOM couplers for a cavity. Each cavity has a liquid He vessel which reduces the coldmass and allow a gently fast cooldown and warmup of cavity.

Figure 2. Schematic layout of the TESLA Test Facility (TTF)
Figure 3. TESLA cavity with LHe vessel & 2K forward line, and a picture of the prototype cavity

Table 3. Parameters of the TESLA cavity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Freq.</td>
<td>1.3 GHz</td>
</tr>
<tr>
<td>Cavity cell</td>
<td>9</td>
</tr>
<tr>
<td>Effective length</td>
<td>1.035 m</td>
</tr>
<tr>
<td>Bpeak/Eacc</td>
<td>4.2 mT/MV/m</td>
</tr>
<tr>
<td>Peak RF power</td>
<td>206 kV/m</td>
</tr>
<tr>
<td>Cryo load module</td>
<td>21.4 W</td>
</tr>
<tr>
<td>Coupling cell-cell</td>
<td>1.87%</td>
</tr>
<tr>
<td>Gradient</td>
<td>25 MV/m</td>
</tr>
<tr>
<td>Cavity aperture</td>
<td>35 mm-radius</td>
</tr>
<tr>
<td>Epeak/Eacc</td>
<td>2</td>
</tr>
<tr>
<td>R/Q</td>
<td>1011 Ω/cavity</td>
</tr>
<tr>
<td>Stored energy</td>
<td>0.127 J/(MV/m)^2</td>
</tr>
<tr>
<td>G(Rs=G/Qo)</td>
<td>271</td>
</tr>
<tr>
<td>HOM K(II)</td>
<td>9.24 V/pC</td>
</tr>
</tbody>
</table>

FIGHTING FOR HIGHEST ACCELERATING GRADIENT -- AN ULTIMATE TASK

The TESLA collaboration aims for the highest operating gradients Eacc in SRF cavities using economically affordable approaches.

Theoretical Limit of Eacc

The limit magnetic field in RF is larger than Bc (type I superconductors) and Bc1 (type II) respectively, and is called superheating critical field Bsh. Table 3 gives the Bsh values of typical materials studied in SRF technology compared with the maximum surface field Bexp experimentally obtained so far. Using a common accepted rule of thumb that 40 Gauss (4mT) is equivalent to 1 MV/m accelerating gradient in cavities with β = 1, the limit for Nb is then about 60 MV/m, and for Nb3Sn, 100 MV/m.

Table 4. Critical field in DC and RF superconductivity

<table>
<thead>
<tr>
<th>Materials</th>
<th>Tc [K]</th>
<th>Bdc [mT]</th>
<th>Bcl [mT]</th>
<th>Bc2 [mT]</th>
<th>Bsh [mT]</th>
<th>Bexp [mT]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn</td>
<td>3.7</td>
<td>30.9</td>
<td>-</td>
<td>-</td>
<td>68</td>
<td>30.6</td>
</tr>
<tr>
<td>In</td>
<td>3.4</td>
<td>29.3</td>
<td>-</td>
<td>-</td>
<td>104</td>
<td>28.4</td>
</tr>
<tr>
<td>Pb</td>
<td>7.2</td>
<td>80.4</td>
<td>-</td>
<td>-</td>
<td>105</td>
<td>112</td>
</tr>
<tr>
<td>Nb</td>
<td>9.2</td>
<td>200</td>
<td>185</td>
<td>420</td>
<td>240</td>
<td>160</td>
</tr>
<tr>
<td>Nb3Sn</td>
<td>18.2</td>
<td>535</td>
<td>20</td>
<td>2400</td>
<td>400</td>
<td>106</td>
</tr>
</tbody>
</table>

Bdc - thermodynamic critical field
Bsh - superheating critical field
Bexp - experimentally obtained maximum field

All data refer to values at T = 0 K
Achievements and Limit in Operating Accelerators

Since the early 1970s, significant progress in developing a state of the art SRF accelerating cavity have been achieved. The operating accelerating gradients in more than 10 laboratories (such as Argonne\textsuperscript{10}, CEBAF\textsuperscript{11}, CERN\textsuperscript{12}, Cornell\textsuperscript{13}, Darmstadt\textsuperscript{14}, DESY\textsuperscript{15}, KEK\textsuperscript{16}, Saclay\textsuperscript{17}, etc.) and 400 structures reached 5-10 MV/m, compared to design goal of 5 MV/m. These achievements are attributed to anti-multipactor, round cell shape, high thermal conductivity Nb to avoid thermal breakdown (TB), clean surface preparation to avoid field emission (FE). However, the excellent performance of the operating cavities is not adequate for the proposed TESLA machine of $E_{acc} \geq 25$ MV/m and $Q \geq 5 \times 10^{9}$. The main obstacles still to overcome are FE and TB. Investigation and elimination of FE and TB have become one of the highest priorities in TESLA and TTF project.

Understanding FE and TB

Significant efforts have been contributed to understanding and defeating the FE and TB in the TESLA Collaboration.

Electrons on cavity surface can be pulled into and accelerated in the cavity vacuum by RF electrical fields. These field emitted electrons absorb energy from RF fields and deposit the energy in their landing area on the cavity, resulting in degradation of $Q$ value and limit the $E_{acc}$. Studies with DC FE scanning microscope and in SRF cavities\textsuperscript{18,19,20,21} indicate that most FE electrons come from submicro-size foreign particles of a metallic nature with irregular shapes. Some studies also found that the condensed gases and heat treatment at 200-600 C will activate FE\textsuperscript{21,22}. Thermal breakdown is due to imperfections of the RF surface. For a given imperfection, the thermal breakdown field scales roughly as the (thermal conductivity)$^{1/2}$. Within SRF community the residual resistance ratio (RRR) is used to characterise the thermal conductivity in a convenient way.

It is impossible to directly observe the FE and TB through inner surface of cavities during RF operation. Therefore, the main approach to understanding the FE and TB of cavities is to study the hot spots and X-rays (induced by impacting FE electrons) generated on the cavity surfaces during RF operation. At DESY a rotating T-R mapping system for TESLA 9-cell cavities has been developed and more than 10,000 spots on the cavity can be

Figure 4. Rotating T-R mapping system for diagnostics of TESLA 9-cell cavities.  
Figure 5. The ultrahigh vacuum oven for Ti-gettering purification of cavities
investigated in one turn with 10° stepping. We have used it to successfully identified the TB location, traced the dynamic progress of cavity quench, located the heating areas by FE electrons and simulated the emitter locations.

Fighting FE and TB

For years in many laboratories around the world, there have emerged many comprehensive approaches for cavities processing in order to reach the highest possible gradient. Many of these approaches have been adopted, further developed and used by TESLA collaboration at DESY.

Fighting TB with UHV Oven.

Over the last 10 years the RRR of sheet Nb delivered by industry for cavities has been improved to 300 from 30 by better melting practices removing most of the dissolved impurities of O, N, H, C, etc. Cavities using these sheets produce a range of TB at 13 - 19 MV/m. Higher RRR of > 500 is desired for reaching a $E_{acc} > 25$ MV/m. Currently the way to further higher RRR is to employ solid state gettering. In this technique, both the inside and outside surface of a prepared cavity are exposed to Ti vapors at 1400°C for 4 hrs. The oxygen which diffuses to the cavity surface is gettered in solid state by the evaporated layer. After improvement of RRR, both surfaces are etched to remove the foreign metal layer. Figure 5 is the UHV oven used at DESY (1400°C at 10^-7 mbar). The monitory sample Nb indicate that RRR of 250-300 of cavity material is raised to > 500 after the Ti-purification treatment. Several TESLA 9-cell cavities show $E_{acc}$ increase of to 20 - 26 MV/m.

Also the UHV oven has played an important role in eliminate the FE and control the hydrogen content of Nb in eliminating the "H-desease".

Cleaning Technology Defeating FE

The cleaning techniques is used to remove all FE particles out of cavities RF surfaces similar to that method utilized in semiconductor industry. These cleanliness during chemical etching, water rinsing (high purity water of 15 MΩ-m) and assembling have played a important role in higher $E_{acc}$. The high pressure water rinsing (HPR) device made by CERN for the TESLA collaboration is very helpful in removing foreign particles.

Figure 6. The clean room for cavity processing and assembling.

Figure 7. Chemistry and rinsing of cavity in the clean room.
which are difficult to be removed by regularly water rising. Several prototype TESLA cavities after HPR (without Ti-purification) produce Eacc > 15 MV/m.

We built a clean room of 300 m² with class 10 and 100 areas in 1993 consisting of chemical etching, HPR, and cavity assembling room (also we can load cavity to UHV oven in a clean room area. The capability of HPR is as high as 200 bar. Figure 6 is a part of the clean room and Figure 7 shows the clean chemical etching of a TESLA cavity.

High RF Peak Power Processing - Last Chance to Beat FE.

Despite how good a job we (and you) perform to eliminate the FE, there is always a possibility that particles escape removal even with all the careful preparation, and stay on cavities surface. Therefore a technique that can eliminate the emitters in situ is highly desirable. The technical, so called HPP - high power processing developed at cornell university, is to apply a high pulse RF power cavity in situ and eliminate the FE through explosive process 26. The idea is to raise the electric field at emitter as high as possible in a short time (μs - ms) that generates a very high FE current. The transient high current melts, evaporates and activates a RF spark to destroy the FE emitters. The high RF pulse power processing of cavities provides a final, effective way to destroy the remaining FE emitters 22. At DESY a HPP facility has been used successfully in raising Eacc. The peak power of klystron is 4.5 MW with pulse length of 2 ms.

The key technologies we have used to fight FE and TB can be summarized in Table 4.

Table 4. Key technologies of cavities processing for highest Eacc

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Short Description</th>
<th>Impact on FE</th>
<th>Impact on TB</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean cavity handling</td>
<td>Class 10-100 clean room for chemistry, rinsing &amp; assembling</td>
<td>Eliminating foreign particle contamination</td>
<td>Deep chemistry may remove some impurities</td>
<td>Good for Q and Eacc</td>
</tr>
<tr>
<td>Heat treatment + Ti-purification in UHV oven</td>
<td>Heat cavity at 1400 C for 1-4 hrs, Ti vapor coated in vacuum</td>
<td>Greatly reduce emitters existing on cavities</td>
<td>Improve RRR by a factor of 2. (improve K)</td>
<td>Substantially increase Q and Eacc</td>
</tr>
<tr>
<td>High pressure water rinse 24</td>
<td>Rinse cavity by high purity water (15 MΩm) at 200 bar</td>
<td>Reduce emitters density</td>
<td></td>
<td>Increase Q and Eacc</td>
</tr>
<tr>
<td>High RF power processing</td>
<td>Apply high RF power pulse (1-2 MW, μs-ms) to cavity surface</td>
<td>Eliminate emitters in situ</td>
<td></td>
<td>Substantially increase Q and Eacc</td>
</tr>
</tbody>
</table>

Encouraging Achievements with TTF Project

With the above techniques, we significantly increase thermal conductivity and

Figure 8. (A) Q vs. Eacc plots of TTF 9-cell cavity -1. (B) The performance of cavity D2 in pulse RF condition similar to TTF operation. 26 MV/m of Eacc is reached.
reduce FE emitters. Two 9-cell TTF prototype cavities reached respectively $\text{Eacc} = 16 \text{ MV/m}$ and $21 \text{ MV/m}$ both $Q > 6 \times 10^9$ in CW. The first series TTF 9-cell cavity (RRR=350) reached $\text{Eacc}=26 \text{ MV/m}$ in 1 ms RF power length (TESLA operational condition) and 22 MV/m in cw 27. Also, a TTF enjector cavity provided by Saclay reached $21 \text{ MV/m}$, $Q > 4 \times 10^9$. Compared to a TTF goal of $\text{Eacc}=15 \text{ MV/m}$ and $Q=3 \times 10^9$, the initial result is very encouraging. However, there are two cavities which met TB at $\text{Eacc} = 12$ and 15 MV/m respectively. It is considered that removing an additional 50-80μm materials from cavity surfaces will be useful in improvement of thermal conductivity of the cavity wall. Continuing progresses is expected with improvements in processing technologies and diagnostic testing. Some representative results are plotted in figure 8.

**TESLA PROTOTYPE CRYOMODULE**

The cryomodule is 12 m long and consists of 8 SRF cavities with LH$\text{e}$ vessels, one quadrupole magnet package, associate fixtures (RF couplers, tuner, alignments, etc.) and a cryostat in which all the above components are housed. The TTF cryomodule also has some special requirements due to SRF cavity technologies. For instance:

1. To eliminate FE, the eight cavities and quadrupole package must be assembled together in a clean room and be inserted in the cryostat as a single UHV tight unit.
2. To improve cavity $Q$ value, restricted magnetic shields are needed to reduce residual earth magnetic fields to less than 20 mGauss.
3. Due to beam dynamic consideration, the axes of eight cavities to the ideal beam axis need to be within $\pm 0.5$mm.

Based upon cost effective design philosophy, most of the needs for keeping such special technical features must be addressed in the cryostat design. Figure 9 is a cross section of TTF cryomodule $^3$.

![Figure 9. A cross section of TTF cryomodule.](image)
TTF Cryostat

The technical features and design details of cryostat are introduced in the references 28, 29 of this conf. The total heat load to 2K from a cryomodule estimated is 21.4 W. The anticipated static heat load budget for one cryomodule is 4W at 2K, 14W at 4.5K and 120 W at 70K 28, 29, 30. Since dominate heat load in cryomodule is RF dynamic heating, not static heat leak, the primary interest of measuring the heat load is to verify the RF dynamic load out of the total heat load. With the heat attributed to the RF loss, we can calculated the Q of each individual cavity or cavities. A comprehensive verification plan have been developed3 (with about 135 thermometers, 2 accelerometers, etc.) that will also allow us to study the heat leak through the power and HOM coupler and the thermal performance of the cryostat as well.

Special Magnetic Shield

The trapped magnetic flux from ambient fields (even less than 3 gauss) during cool down will seriously impact the cavity performance. In case of RF fields, the trapped flux will raise the RF power dissipation and gives an equivalent local residual resistance about $R_s = R_n x (H/H_{c2})x\sin\alpha$. To TESLA cavity (RRR=300, f=1.3 GHz), a convention factor of 0.35 nΩ/mGauss closely matched experimental data. In order to get Q value = 5x10$^9$ specified for TESLA, surface resistance can not be larger than 25 nΩ, equivalent to 70 mGauss. Considering other contributions to the residual resistance and possibly increasing the Q, the remaining field around the TESLA-TTF cavities should be ≤ 20 mGauss. There are two shielding approaches in use, passive shields made of Cryoperm and active cancellation coil, both of which have been designed and examined31.

Quadrapole Package

There is a quadrapole package 32 as shown in Figure 10, located at the end of each cryomodule, which includes: (1) a superfic quadrupole doublet (maximum gradient of 20 T/m and integrated gradient of 3T at 55.7 A) enclosed in a 4K LHe vessel, (2) two pairs of single layer dipole steering winding inside the quadrupole yoke bore, (3) a section of beam tube equipped with a beam position monitor (BPM) and HOM absorber (20 W), and (4) the He gas cold power leads (0.1 g/s) for energising the magnets. At the end plate, there are two arms each holding reference targets for alignment.

Figure 10. A quadrupole package
Power and HOM Couplers

The TESLA input couplers \(^{33, 34}\) are articulated with bellows to allow for cavity moving during cooldown. The couplers also have an adjustable external Q over a factor 10 range. The allowed RF heat load and heat leak are very low. All the above features make the coupler mechanically complicated. The input coupler is directly connected on the cavity cut off tube. It does not penetrate the LHc vessel, but is thermally anchored by the radiation shields with radiation cones. The thermal budget is 6W/70K, 0.5W/4.5K and 0.06W/2K. For TTF, two 5MW peak power klystrons TH 2104C from Thomson will power the four cryomodules and an extra 300 kW pulse klystron is needed for the injector.

To restrict the multi-bunch phenomena due to wakefields, the higher order modes (HOM) \(^{34}\) of the TESLA cavities must be damped (with Qext = \(10^4-10^5\)) by two coaxial HOM couplers for each cavity while the accelerating mode is not effected by the HOM coupler \(^{35}\).

Capture Cavity

Besides the standard cryomodule there is an important cryo-component, called the capture cavity \(^{36}\) in TTF. The capture cavity terminates the bunching upstream and provides the necessary energy for injection into first cryomodule. The capture cavity is a standard TESLA 9-cell cavity and is installed in a separate cryostat at the end of the injector. It shares a common cryogenic feed box with the other four cryomodules. The capture cryostat only has 80K insulation shield with 40 MLI layers. The Epoxy-fibreglass rods are used instead of posts, and its focusing superconducting solenoid magnet is conduction cooled from the 4K loop.

TTF STATUS

A 3000 m\(^2\) of building, Hall III, has been assigned to host the TTF Linac and TTF infrastructure. We plan to deliver a beam through injector and first cryomodule with energy of about 140 MV/m by the end of 1995 (or early 1996). The complete 500 MeV TTF Linac will be commissioned in 1997. Figure 11 is an overview of the TESLA Test Facility.

For cavity processing, a complex clean room of 300m\(^2\) (including a class 10 area), a chemistry etching facility with purity standards equal to semiconductor industry, a high pressure ultra-clean water rinsing system (18 M\(\Omega\)-m, 200 bar), an UHV furnace with Ti-gattering purification fixture at about 1400 C, 10\(^{-7}\)mbar, a high pulse peak power RF processing system with up to 2 MW peak power, and a modulator and klystron of 4.5MW,

![Figure 11](image-url)  
*Figure 11. Overview of the TESLA Test Facility (TTF) at DESY.*
2ms have been installed and commissioned. For testing, a LH2 cryogenic system with the warm vacuum compressor assembly of handling 10 g/s He at a pressure of 10 mbar and cooling capability of 100 W at 1.8K (at maximum liquefaction of about 5 g/s). 400W/4.5K and 2000W/70K is in normal operation. As second stage, the plant will be expanded to 200 W/1.8 K with 10 g/s liquefaction. Two vertical test cryostats (one in use) and a horizontal test cryostat with RF system are installed. A rotating temperature and radiation mapping diagnostic system is also used to analyse the cavity performance. Control system and data base system are under development.

ACKNOWLEDGEMENTS

The author sincerely thanks many colleagues for the fruitful discussions and valuable information from CEBAF, CERN, Cornell, Darmstadt, DESY, INFIN, KEK, Orsay and Saclay in the TESLA collaboration. All the assistance enables the author to contribute the paper to CEC/ICMC-95, Columbus Ohio, USA.

REFERENCES

9. G. Horlitz, TU-A2, the same CEC/ICMC-95
12. C. Reece, Proc. PAC-95 conf. Dallas, TX, USA, to be published.
16. A. Akai, ibid ref. 4, 1992
17. B. Bonin, et al, ibid ref. 5, 1994
27. S. Wolff, Proc. PAC-95 conf. Dallas, TX, USA, to be published.