Magnetically Damped Furnace
Bitter Magnet Coil 1

FINAL REPORT

M. D. Bird
INTRODUCTION

A magnet has been built by the National High Magnetic Field Laboratory for NASA on a cost reimbursement contract. The magnet is intended to demonstrate the technology and feasibility of building a magnet for space based crystal growth. A Bitter magnet (named after Francis Bitter, its inventor) was built consisting of four split coils electrically in series and hydraulically in parallel. The coils are housed in a steel vessel to reduce the fringe field and provide some on-axis field enhancement. The steel was nickel plated and Teflon coated to minimize interaction with the water cooling system. The magnet provides 0.14 T in a 184 mm bore with 3 kW of power.

TEST PROCEDURE AND DATA

I MASS

| Maximum mass of magnet empty: | 100 kg |
| Measured mass of magnet empty: | 77 kg |
| Measured mass of magnet full: | 79 kg |
| Measured by: | O'Reilly, Loffelbein |
| Equipment Used: | Pelouze Model 4040 400 lb Capacity Digital Scale +/- 0.2 kg |

II STRUCTURAL AND MECHANICAL

<table>
<thead>
<tr>
<th>Acceleration</th>
<th>(g's)</th>
<th>(m/s^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.6</td>
<td>133.416</td>
</tr>
</tbody>
</table>

SPRING FORCES

| Desired Clamping force (N) | 2000 |
| Spring stiffness (N/mm) | 21.3 |
| Spring free length (mm) | 7.94 |
| Spring solid height (mm) | 4.9 |
| Max. spring displacement (mm) | 3.04 |
| Max. spring force/spring (N) | 64.8 |
| # of springs | 50 |
| Max. spring force/coil (N) | 3238 |
| Max. spring force tot (N) | 12950 |

COIL MASSES AND G FORCES

<table>
<thead>
<tr>
<th>Coil #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>coil mass (kg)</td>
<td>7.4</td>
<td>9</td>
<td>11.2</td>
<td>15.2</td>
</tr>
<tr>
<td>Accel. Force (N)</td>
<td>987</td>
<td>1201</td>
<td>1494</td>
<td>2028</td>
</tr>
<tr>
<td>Total mass (kg)</td>
<td>42.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total force (N)</td>
<td>5710</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HYDRAULIC FORCES
Water Pressure (MPa) 0.02
Head area (mm^2) 65182
Pressure load (N) 1304

DESIGN FORCE
Design force (N) 14254

STAND-OFF ROD COMPRESSION
length (mm) 53
diameter of rods (mm) 5
number of rods 24
area (mm^2) 471
Stress (MPa) 30
Yield stress (MPa) 210
Safety factor 6.9

HEAD DEFLECTION: see Roark's formulas for stress and strain pg. 405

Outer radius a (mm) 172
Inner radius b (mm) 94
Thickness t (mm) 7
Young's modulus E (MPa) 2.10E+05
Poisson's ratio nu 0.30
Bending stiffness D 6.60E+06 (N*mm)
distributed load q (MPa) 2.19E-01

C1 0.4392
C7 0.5839
C4 0.9957
L11 0.0014
L14 0.0118
L17 0.0768

Displacement at inner radius
simple support
yb (mm) 1.64
thetb(rad) 0.02
theta(rad) 0.02

clamped
Displacement at inner radius yb (mm) 0.11
Moment at outer radius Mra (N) -452
Stress at outer radius Sra (MPa) -55.4
Yield Stress Sy (MPa) -210
safety factor 3.79
VESSEL SHELL TENSION

vessel section (mm^2) 5404  
vessel Sss (MPa) 2.64  
vessel strain 1.26E-05  
vessel length (mm) 218  
vessel DL (mm) 0.27  
yield stress (MPa) 210  
safety factor 8 0

SCREW TENSION

screw section (mm^2) 14.2  
# of screws 1 8  
total moment at outer radius (Nmm) -488761  
moment per screw (Nmm) -27153  
moment arm (mm) 6.25  
screw tension (N) 4345  
proof load (N) 8230  
safety factor 1.89

III MATERIAL COMPATIBILITY

A complete drawing package was sent to NASA and was approved before construction began. A package of as-built drawings is enclosed. Materials in contact with coolant consist of the following: stainless steel, nickel, Teflon, Kapton.

IV. DIMENSIONS

<table>
<thead>
<tr>
<th></th>
<th>Required</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>238.1 mm max.</td>
<td>239.44, 239.58 mm</td>
</tr>
<tr>
<td>Inside diameter</td>
<td>184.2 mm min.</td>
<td>184.24, 184.26 mm</td>
</tr>
<tr>
<td>Outside diameter</td>
<td>361.95 mm max.</td>
<td>341.78, 341.42 mm</td>
</tr>
<tr>
<td>Measured by:</td>
<td>Bird, O'Reilly</td>
<td></td>
</tr>
<tr>
<td>Equipment used:</td>
<td>Mitutoyo 0-55 cm caliper</td>
<td></td>
</tr>
</tbody>
</table>

V. FIELD STRENGTH AND HOMOGENEITY

The water flow through the magnet was set at 640 ml/10 sec (230 kg/hr) as measured with a graduated cylinder and stopwatch. The current was set at 20.88, 27.87 and 31.86 Amps as measured by a shunt and multimeter. The voltage across the coil was measured at 52.28, 76.80 and 92.99 Volts for the three current settings, respectively. The electrical power consumed during the three measurements was 1092, 2140, and 2963 Watts, respectively. The field was mapped along the axis of the magnet using a Hall probe, Hall probe holder, and gaussmeter. The recorded data follows:
<table>
<thead>
<tr>
<th>pos. (mm)</th>
<th>Field (mT)</th>
<th>Field (mT)</th>
<th>Field (mT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>76.5</td>
<td>105.9</td>
<td>124.4</td>
</tr>
<tr>
<td>64</td>
<td>81.3</td>
<td>112.6</td>
<td>131.8</td>
</tr>
<tr>
<td>79</td>
<td>83.9</td>
<td>116.2</td>
<td>135.3</td>
</tr>
<tr>
<td>94</td>
<td>84.8</td>
<td>117.6</td>
<td>136.5</td>
</tr>
<tr>
<td>109</td>
<td>85.1</td>
<td>118.0</td>
<td>136.4</td>
</tr>
<tr>
<td>124</td>
<td>85.5</td>
<td>118.4</td>
<td>136.4</td>
</tr>
<tr>
<td>139</td>
<td>86.1</td>
<td>119.0</td>
<td>136.8</td>
</tr>
<tr>
<td>154</td>
<td>86.6</td>
<td>119.5</td>
<td>136.9</td>
</tr>
<tr>
<td>169</td>
<td>86.1</td>
<td>118.7</td>
<td>135.4</td>
</tr>
<tr>
<td>184</td>
<td>83.7</td>
<td>115.2</td>
<td>130.9</td>
</tr>
<tr>
<td>199</td>
<td>78.4</td>
<td>107.9</td>
<td>122.4</td>
</tr>
</tbody>
</table>

1 kW Field Profile

![1 kW Field Profile Graph](image)
Field variation over 150 mm: 1 kW = 8.2%, 2 kW = 11.4%, 3 kW = 9.1%. Specification: < 10 % at 3 kW.
Equipment used: ABB/Alpha Scientific 20kA, 500 V power supply; Weston KS9442-L6 150 A, 50 mV shunt; Keithley 2001 Multimeter (2), Lakeshore 420 Gaussmeter; Lakeshore MMA-2502-VG axial metal stem Hall probe; NHMFL RES/TOL-1 hall probe holder, Kartell, 1000 mL graduated cylinder; Fischer-Scientific Digital Dual Channel Thermometer; Micronta 63-5012 LCD electronic stopwatch

VI. POWER
See item V.

VII. ELECTRICAL ISOLATION

Required line to chassis isolation: 2 Megohms
Measured line to chassis isolation: 500 Megohms at 500 V
Equipment used: AEMC model 1000 Megohmmeter

VII. PHYSICAL POWER INTERFACE

The MDF-BC1 provides screw lug connectors capable of utilizing 8 gage wire within the zone shown in Figure 3.1.3-1 of the MDF-BC1 specifications.

VIII. COOLANT LOOP PHYSICAL CONNECTIONS

Fluid connectors are male 37 degree flare fittings size 6 per commercial equivalent of military standard 3365.

IX. INLET/OUTLET TEMPERATURE OF MDF-BC1 COOLANT

Set flow at 232 kg/hr. and measure temperature rise at 1, 2 and 3 kW.

<table>
<thead>
<tr>
<th>I (Amps)</th>
<th>V (Volts)</th>
<th>Tin (C)</th>
<th>Tout (C)</th>
<th>Q (kg/hr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.88</td>
<td>52.28</td>
<td>12.4</td>
<td>13.3</td>
<td>230</td>
</tr>
<tr>
<td>27.87</td>
<td>76.80</td>
<td>12.5</td>
<td>15.5</td>
<td>230</td>
</tr>
<tr>
<td>31.86</td>
<td>92.99</td>
<td>12.6</td>
<td>19.4</td>
<td>230</td>
</tr>
</tbody>
</table>

Performed by: Bird, Bole, Loffelbein, O'Reilly
Equipment used: see V
X. COOLANT FLOW RATE/ PRESSURE DROP

<table>
<thead>
<tr>
<th>Flow (mL/10s)</th>
<th>Flow (kg/hr)</th>
<th>DP (psi)</th>
<th>DP (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>510</td>
<td>184</td>
<td>1.2</td>
<td>8</td>
</tr>
<tr>
<td>610</td>
<td>220</td>
<td>1.5</td>
<td>10</td>
</tr>
<tr>
<td>630</td>
<td>227</td>
<td>2.0</td>
<td>14</td>
</tr>
<tr>
<td>700</td>
<td>252</td>
<td>2.0</td>
<td>14</td>
</tr>
<tr>
<td>740</td>
<td>266</td>
<td>2.3</td>
<td>16</td>
</tr>
<tr>
<td>830</td>
<td>299</td>
<td>2.5</td>
<td>17</td>
</tr>
<tr>
<td>870</td>
<td>313</td>
<td>3.0</td>
<td>21</td>
</tr>
<tr>
<td>900</td>
<td>324</td>
<td>3.0</td>
<td>21</td>
</tr>
</tbody>
</table>

Specification: <34.5 kPa at 232 kg/hr.
Measured by: Bird, O'Reilly
Equipment used: Wika -30 in. Hg/ +30 psi gage, 1000 mL graduated cylinder; Pulsar quartz watch.

XI. COOLANT COMPATIBILITY

A complete drawing package was sent to NASA and was approved before construction began. Materials in contact with coolant consist of the following: stainless steel, nickel, Teflon, Kapton.

Magnet water specification at the NHMFL:

- Total dissolved solids (as CaCO₃): 50 ppb
- Total silica (as SiO₂): 10 ppb
- Sodium (as CaCO₃): 40 ppb
- Resistivity: 6 Megohm-cm
- Dissolved Oxygen: 0.02 - 0.03 ppm

XII. ATMOSPHERE

The MDF-BC1 will operate in the following atmospheres:
- 0.1 bar Argon
- 18-45 degrees Centigrade air with 40 - 90% relative humidity

XIII. EXTERNAL FIELD

The field external to the magnet has been measured at the midplane 200 mm from the outside surface of the MDF-BC1 shielding.

<table>
<thead>
<tr>
<th>Required field:</th>
<th>Measured field:</th>
<th>Performed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 kW</td>
<td>3 gauss max.</td>
<td>Bird, Bole, Loffelbein</td>
</tr>
</tbody>
</table>
IXV. PACKAGING

The MDF-BC1 is adequately packaged for damage-free handling. After operation it was drained and dried by blowing compressed air through it for approximately 3 hours. It was then filled with Helium gas and closed.

CONCLUSIONS

The magnet project was successfully completed. Additional magnets could be built if requested. The primary change that could be made to attain higher field and/or uniformity would be to make the magnet longer. However, for this first magnet, the overall length was constrained in the contract to be less than or equal to 238.1 mm. The NHMFL looks forward to receiving results of the tests to be performed at NASA.
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. Ni PLATE 0.013 THICK PER MIL-C-26074E
4. Teflon Coat (0.05 to 0.0127) THICK
5. all dimensions are after plating and coating.

---

DIAGRAM:
- External dimension: 233.50
- Internal dimension: 5.00
- Finish on OD this area only 2 places

---

GENERAL TOLERANCES:
- 1 PL, DEC A & B
- 2 PL, DEC A & B

MATERIAL:
- ALC-219
- ALUMINUM ALLOY

NATIONAL HIGH MAGNETIC FIELD LABORATORY
1800 east paul drive
TALLAHASSEE, FLORIDA 32306-4405

BORE TUBE

SIZE:
RES/HOU-12-02

SCALE 1/1

SHEET 1 OF 1
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE 3/8
3. ELECTROLESS Ni PLATE 0.013 THICK PER MIL-C-26746
(10 - 12% PHOSPHORUS CONTENT), ALL OVER, INCLUDING TAPPED HOLE

SECTION A-A

THD. RELIEF
ROJ TYP
ROJ TYP

M5 X 0.80, 10 DEEP

A

M5 X 1.5 THD

TOOL RADIUS OK

GENERAL TOLERANCES
C3600 - BRASS

FEED-THROUGH

RES/HOU-12-05

NATIONAL HIGH MAGNETIC FIELD LABORATORY
100 EAST PAUL DRACO DRIVE
TALLAHASSEE, FLORIDA 32306-4005

DRAWING NO.
REVIEWED
DRAWN
ISSUE
DATE
SIZE
SCALE
NOTES
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. MATERIAL: Cu, 0.2 THICK
4. ELECTROLESS Ni PLATE 0.013 MAX THICKNESS EACH SIDE
PER MIL-C-26074E (10–12% PHOSPHORUS CONTENT)
5. Teflon Coat (0.05±0.0127) THICK, MASK AS INDICATED

FLAT PATTERN
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. MATERIAL: TEFLOM, 1.0 THICK STOCK
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. MATERIAL: TEFLOW, 1.0 THICK STOCK

REVISED

<table>
<thead>
<tr>
<th>ZONE</th>
<th>REV</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ADED &quot;STOCK&quot; TO NOTE 3</td>
<td>19/12/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DISC C TO DISC B IN NAME</td>
<td>19/12/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHANGED HOLE PATTERN AND DIMS</td>
<td>19/05/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MFG RELEASE</td>
<td>29/05/96</td>
<td></td>
</tr>
</tbody>
</table>

GENERAL TOLERANCES

1 PL DEC 0.25
2 PL DEC 0.10
ANGLES 8°

MATERIAL: SEE NOTE 3.

REVISIONS

NOTE:

1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. MATERIAL: TEFLOW, 1.0 THICK STOCK

REVISED

<table>
<thead>
<tr>
<th>ZONE</th>
<th>REV</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ADED &quot;STOCK&quot; TO NOTE 3</td>
<td>19/12/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DISC C TO DISC B IN NAME</td>
<td>19/12/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHANGED HOLE PATTERN AND DIMS</td>
<td>19/05/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MFG RELEASE</td>
<td>29/05/96</td>
<td></td>
</tr>
</tbody>
</table>

GENERAL TOLERANCES

1 PL DEC 0.25
2 PL DEC 0.10
ANGLES 8°

MATERIAL: SEE NOTE 3.

REVISIONS

NOTE:

1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. MATERIAL: TEFLOW, 1.0 THICK STOCK

REVISED

<table>
<thead>
<tr>
<th>ZONE</th>
<th>REV</th>
<th>DESCRIPTION</th>
<th>DATE</th>
<th>APPROVED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ADED &quot;STOCK&quot; TO NOTE 3</td>
<td>19/12/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DISC C TO DISC B IN NAME</td>
<td>19/12/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHANGED HOLE PATTERN AND DIMS</td>
<td>19/05/95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MFG RELEASE</td>
<td>29/05/96</td>
<td></td>
</tr>
</tbody>
</table>

GENERAL TOLERANCES

1 PL DEC 0.25
2 PL DEC 0.10
ANGLES 8°

MATERIAL: SEE NOTE 3.
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE 2/3

2X R3.2
R12.0
#5.5
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE

SECTION A-A

RADIAL/AXIAL GROOVES - SCALE 10:1

#250 TYP

0.50

3.00

1.00 STOCK

0.114

#190.00

#305.20

16X #2.50
2 PL.

16X #2.50
2 PL. (OD AND ID NOTCHES)

#240.30

#267.50

5.00 WIDE X 0.50 DEEP
16 PLCS. EQUALLY SPACED

#213.90

#189.50

(ID NOTCHES)

#324.50

(ID NOTCHES)

REVISIONS

ZOMI REV DESCRIPTION DATE APPROVED
INITIAL RELEASE
C6 A ADDED "STOCK" 18/12/95
MFG RELEASE 26/06/96

GENERAL TOLERANCES

CERAMIC

1 PL. DEC 8.25
2 PL. DEC 9.10
ANGLES 81°
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE Y
3. MATERIAL: Cu 0.2 THICK
4. ELECTROLESS Ni PLATE 0.013 MAX THICKNESS EACH SIDE
   PER MIL-C-23074E (10-12% PHOSPHORUS CONTENT)
5. TEFON COAT (0.05±0.0127) THICK, MARK AS INDICATED

OWT TEFON COATING THIS FACE

OWT TEFON COATING THIS FACE
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
3. MATERIAL: TEFLOW

HOLE/NOTCH DETAIL - SCALE 5:1

SECTION A-A - SCALE 5:1

16X Ø0.50
2 PL. Ø3 AND OD SPACED AS SHOWN [0.100 ± 0.000]

50X Ø2.50 EQUALLY SPACED [0.100 ± 0.000]
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE

DIMENSIONS:
L = 2.38 STOCK
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE

217.60

2.38 STOCK
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES
2. UNLESS OTHERWISE SPECIFIED MACHINE SURFACE
NOTES:
1. MATERIAL: PYRALUX LF7022, 1.5 MIL CORE.

THICKNESS

R1.25 TYP
SPACED AS TABULATED

0.99 TYP

2X 1.0
EQUALLY SPACED

NOTCH LOCATIONS

NOTCH LOCATIONS MEASURED FROM 0°
POSITIVE IS COUNTERCLOCKWISE
ALL ANGLES ARE BASIC
NOTCH DEPTH AS SHOWN

A B C
190.00 213.40 SEE NOTE 1
214.40 239.60 *
240.80 269.00 *
270.00 304.00 *

GENERAL TOLERANCES

MATERIAL:

INSUL, BITTER, DISKS

NATIONAL HIGH MAGNETIC FIELD LABORATORY
1800 EAST PAUL DRANE DRIVE
TALLAHASSEE, FLORIDA 32308-4005

1 PL, DEC 8.25
2 PL, DEC 8.10
ANGLES 8.1°

ARCHITECTS:

ARCHITECTS:

DRAWN:

DRAWN:

INSURANCE:

INSURANCE:

ARCHITECTS:

ARCHITECTS:

PRINTED:

PRINTED:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS:

ARCHITECTS: