



桥梁工程研究所

风洞实验室

现代监控量测新技术

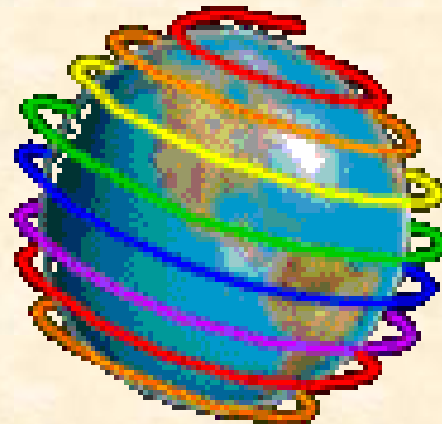
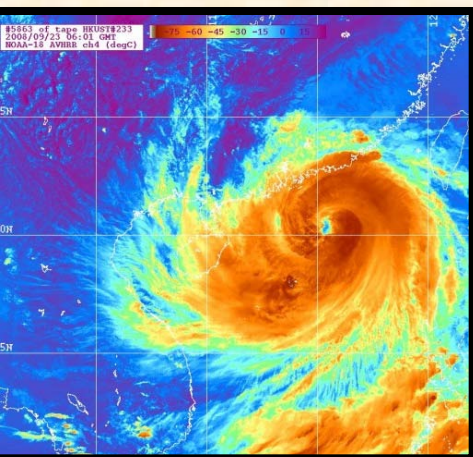
wind



风洞试验测试技术

许福友

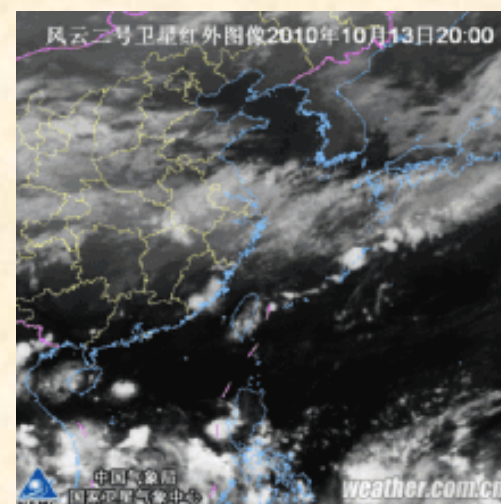
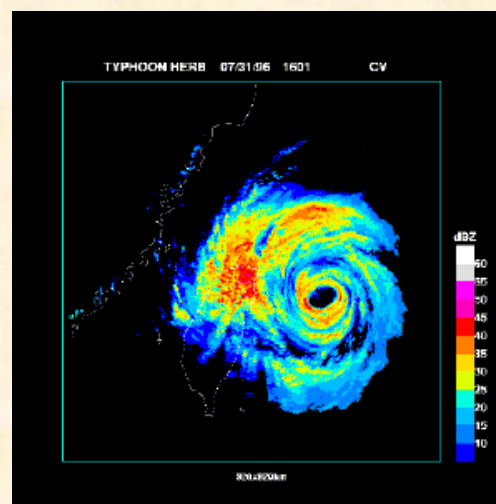
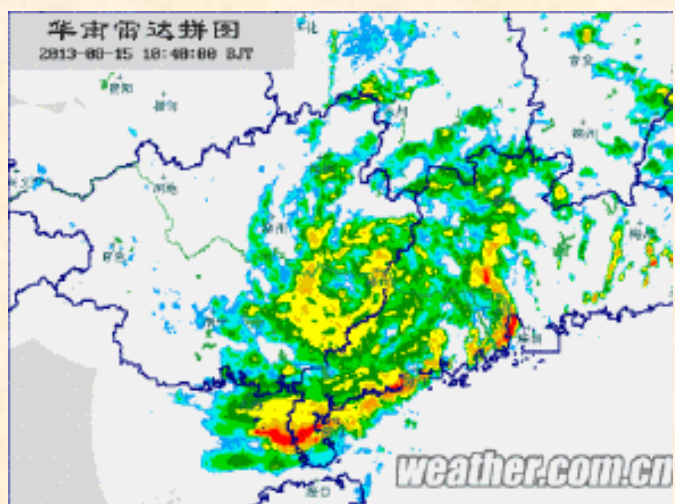
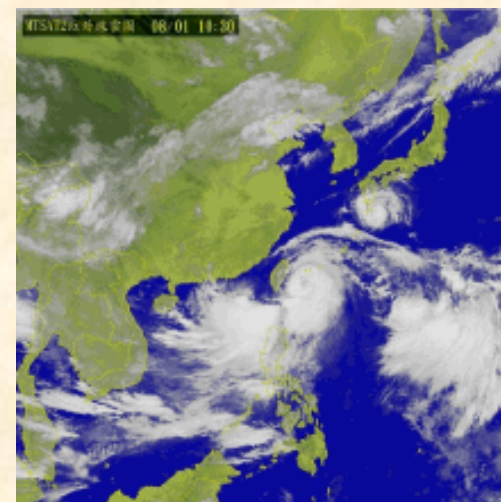
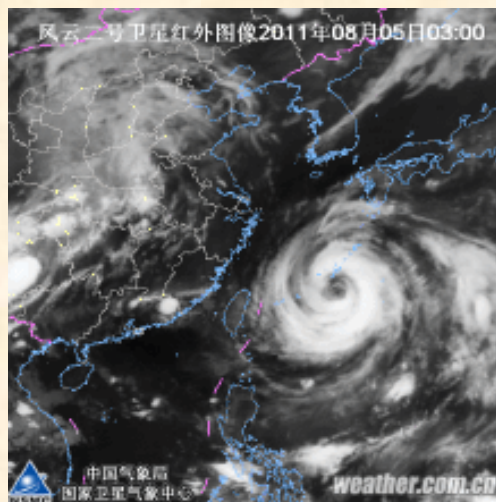
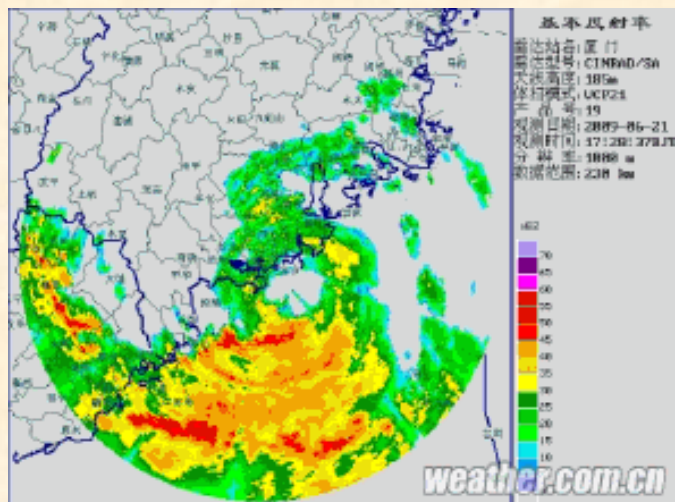
2016年12月16日





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1. 风灾





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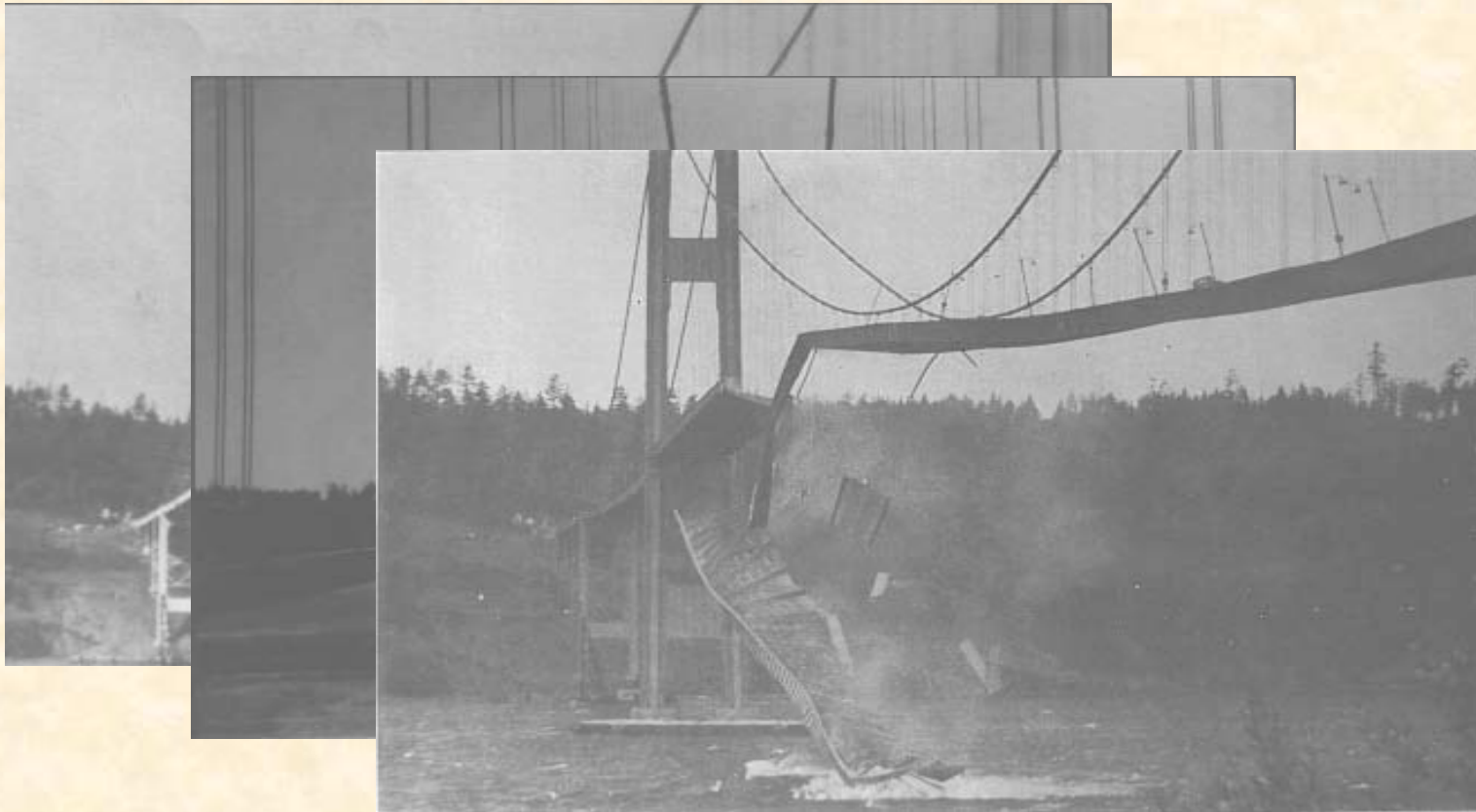
Year	Name	Country	Main span length (ft)	Designer
1818	Dryburgh Abbey	Scotland	260	John&William Smith
1821	Union	England	449	Sir Samuel Brown
1834	Nassau	Genmany	245	Lossen & Wolf
1836	Brighton Chair Pier	England	255	Sir Samuel Brown
1838	Montrose	Scotland	432	Sir Samuel Brown
1839	Menai Strait	Walse	580	Thomas telford
1852	Roche-Beruard	France	641	Le Blanc
1854	Wheeling	USA	1010	Charles Ellet
1864	Lewiston-Queenston	USA	1041	Edward Serrell
1889	Nigara-Clifton	USA	1260	Samuel Keefer
1940	Tacoma narrows	USA	2800	Leon Moisseiff



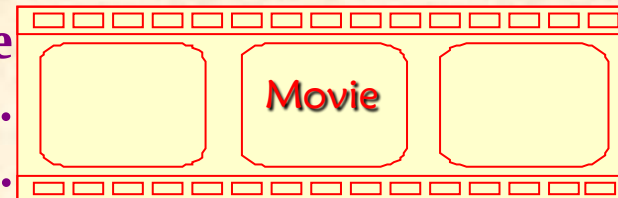
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1. 风灾

Tacoma Narrow Bridge



November 7, 1940, Tacoma Narrows Bridge
Designer: Leon Moisseiff, Velocity: 18~22m/s.
Prof. F.B. Farquharson, University of Washington.

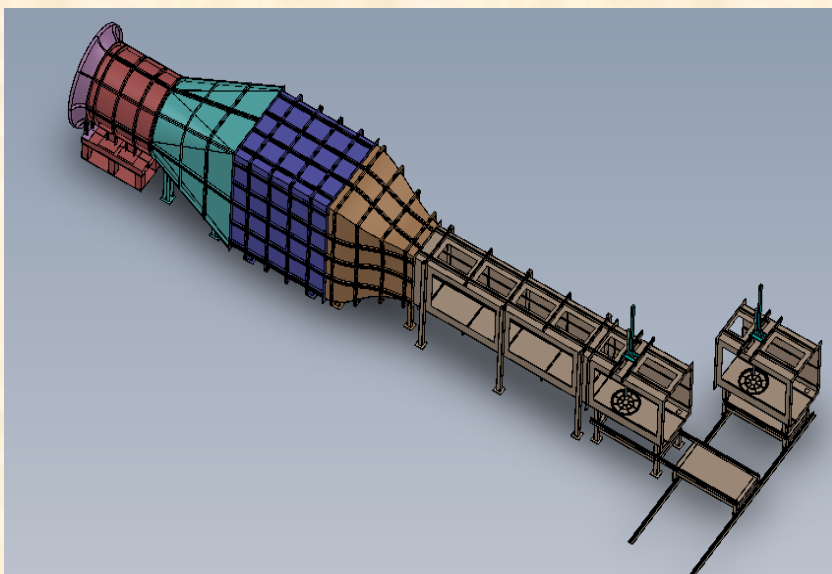




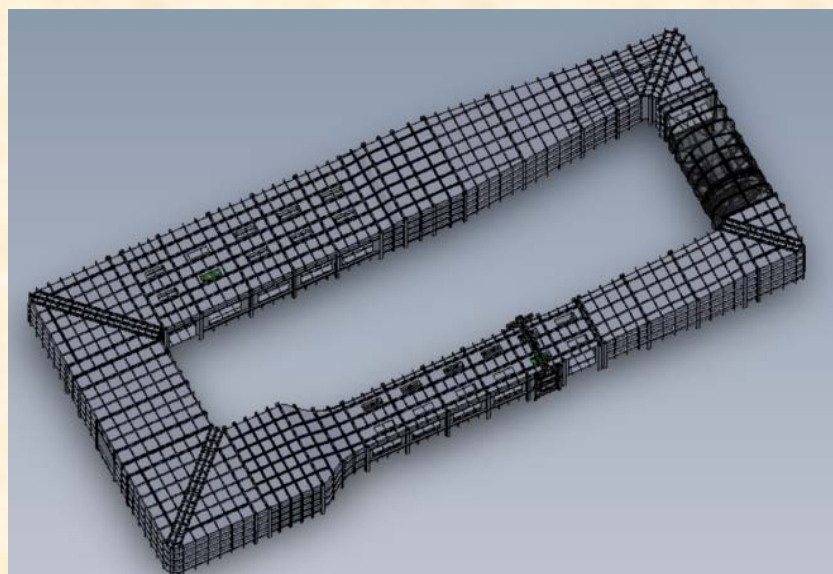
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2. 风洞

风洞 (wind tunnel) 即风洞实验室，是以人工的方式产生并且控制气流，用来模拟飞行器或实体周围气体的流动情况，并可量度气流对实体的作用效果以及观察物理现象的一种管道状实验设备，它是进行空气动力实验最常用、最有效的工具之一。



开口式风洞



循环式风洞



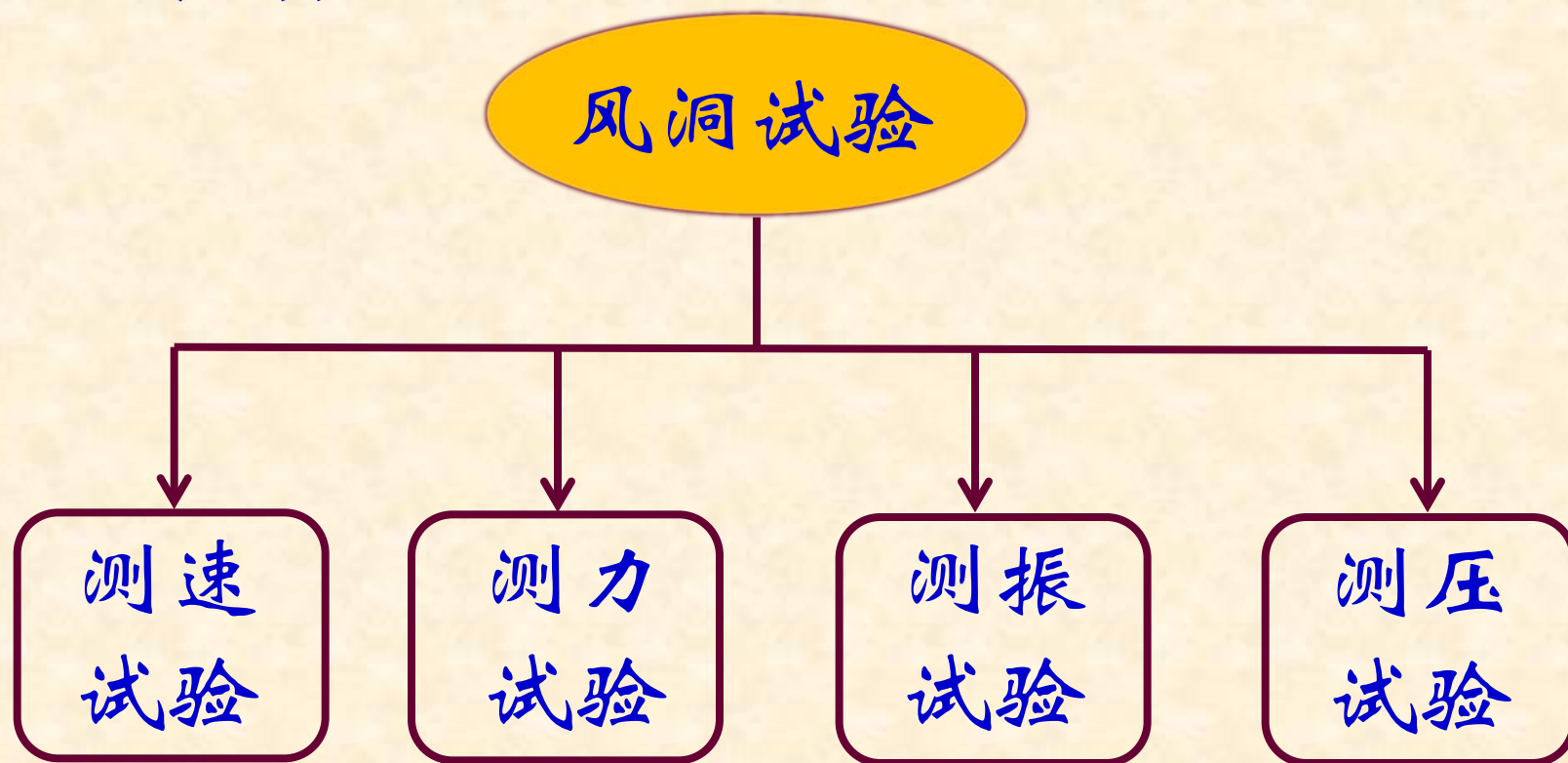
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2. 风洞





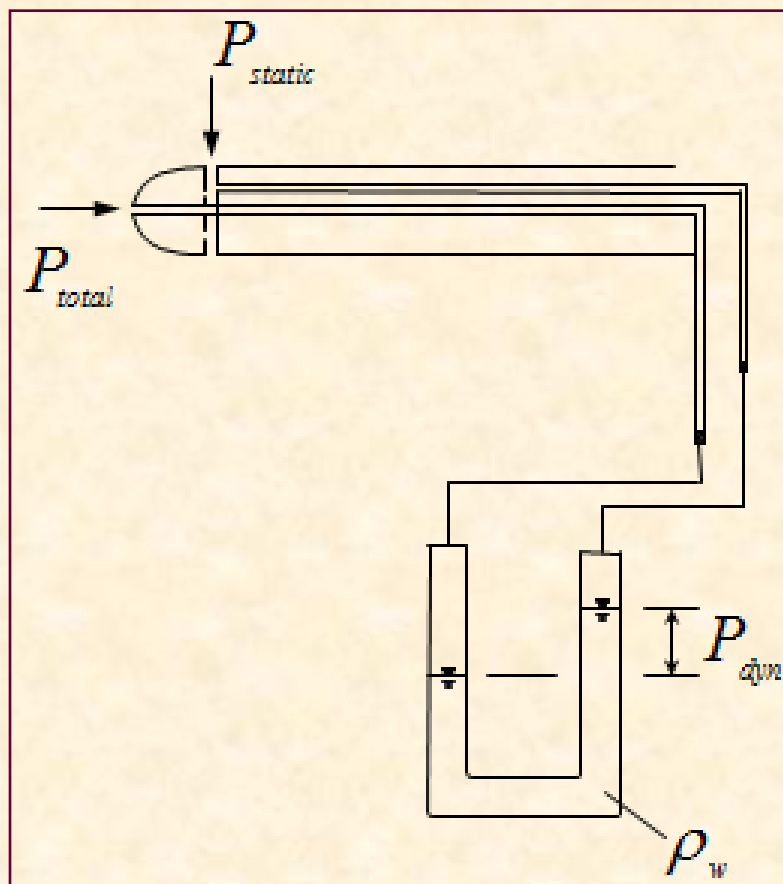
2. 风洞



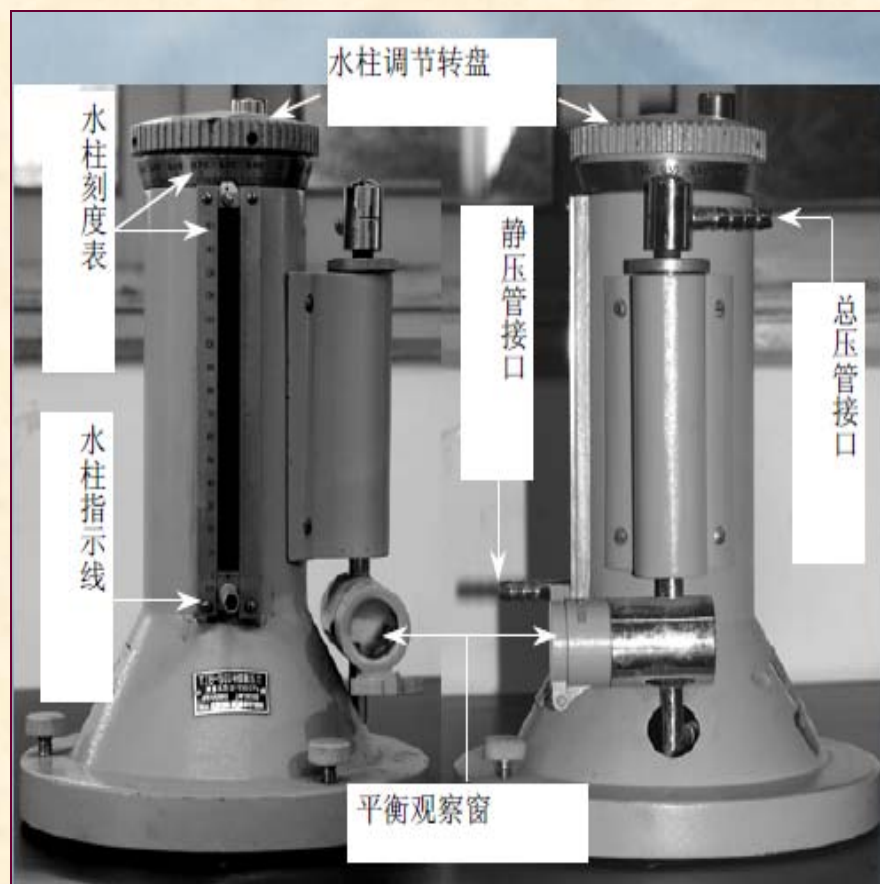


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3. 测速试验



皮托管

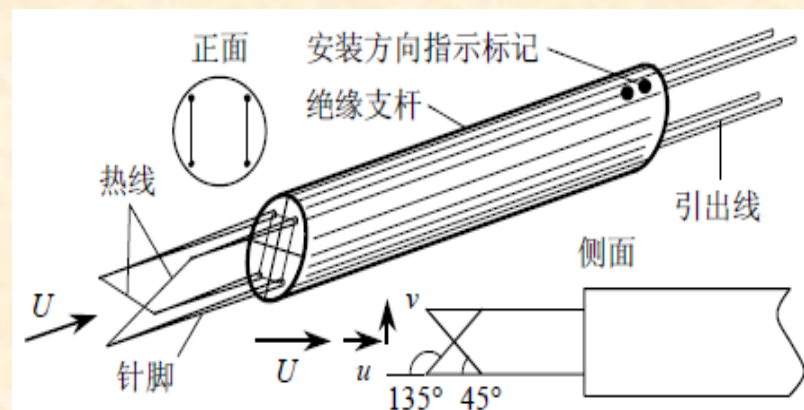
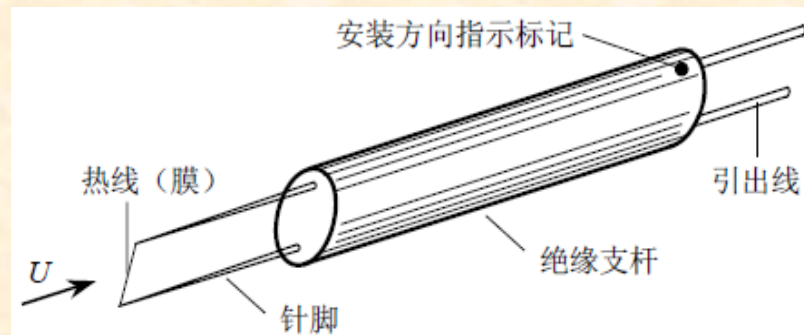


微压计



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3. 测速试验



热线风速仪示意图

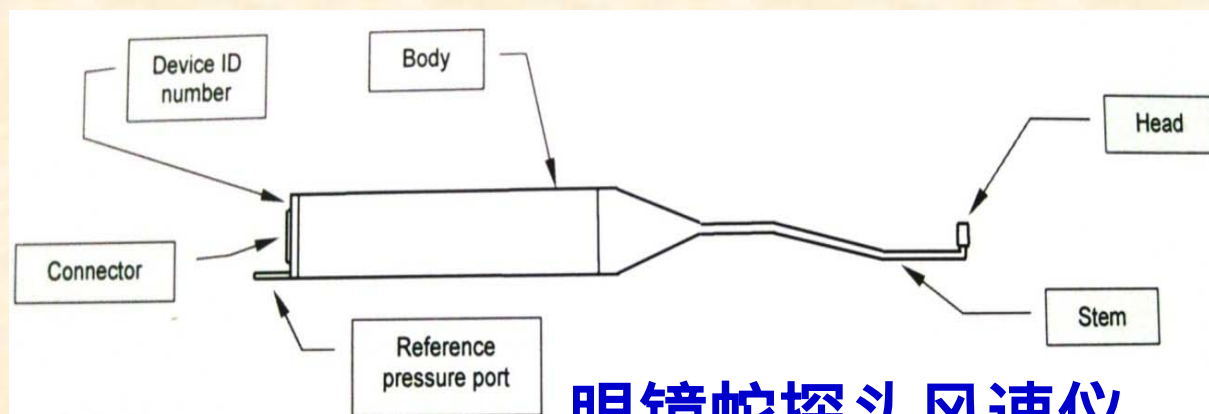


热线风速仪测量系统

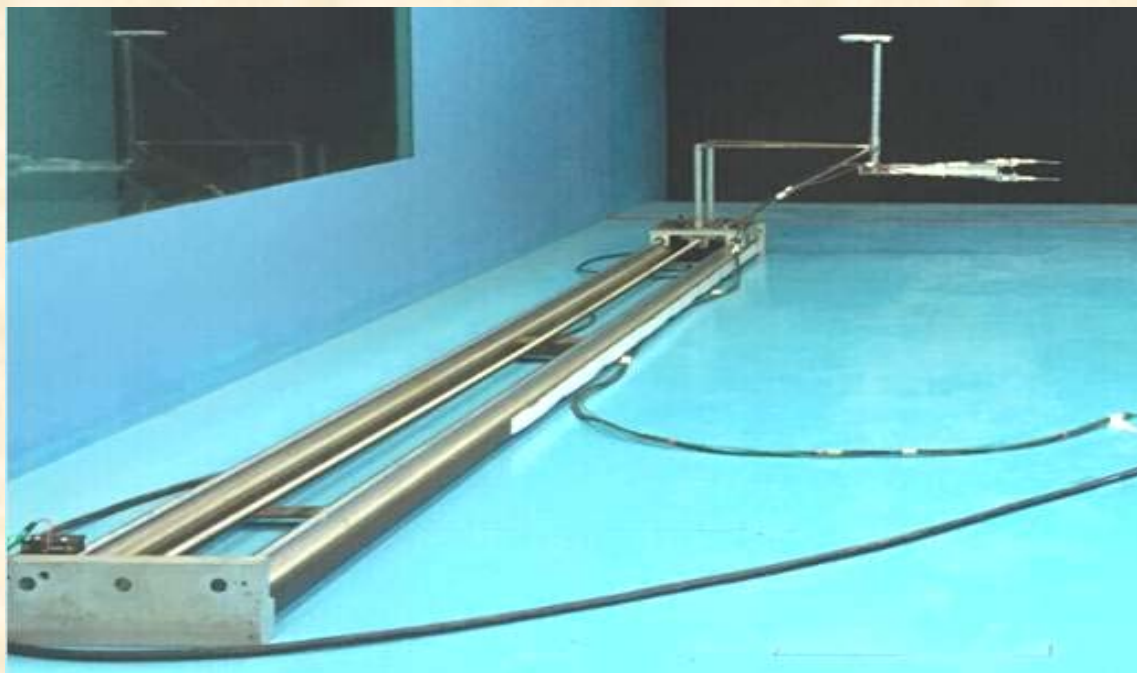
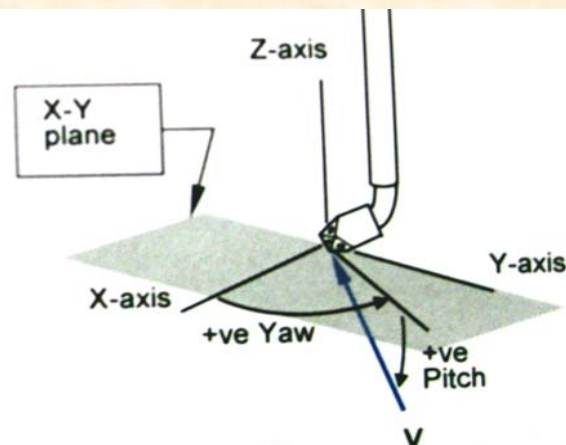


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3. 测速试验



眼镜蛇探头风速仪

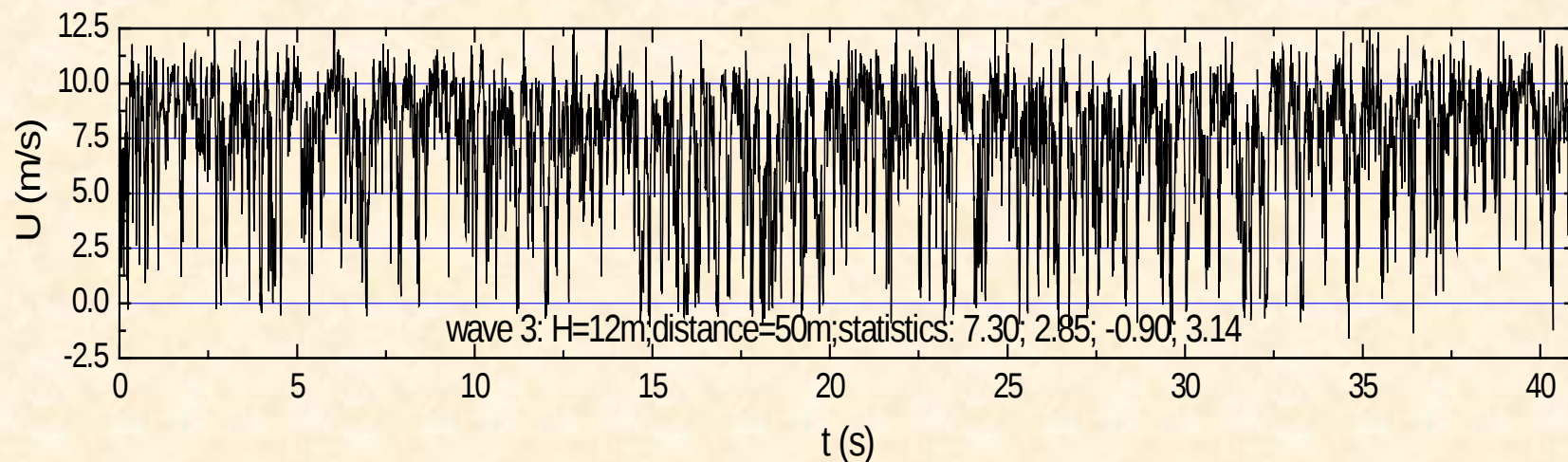
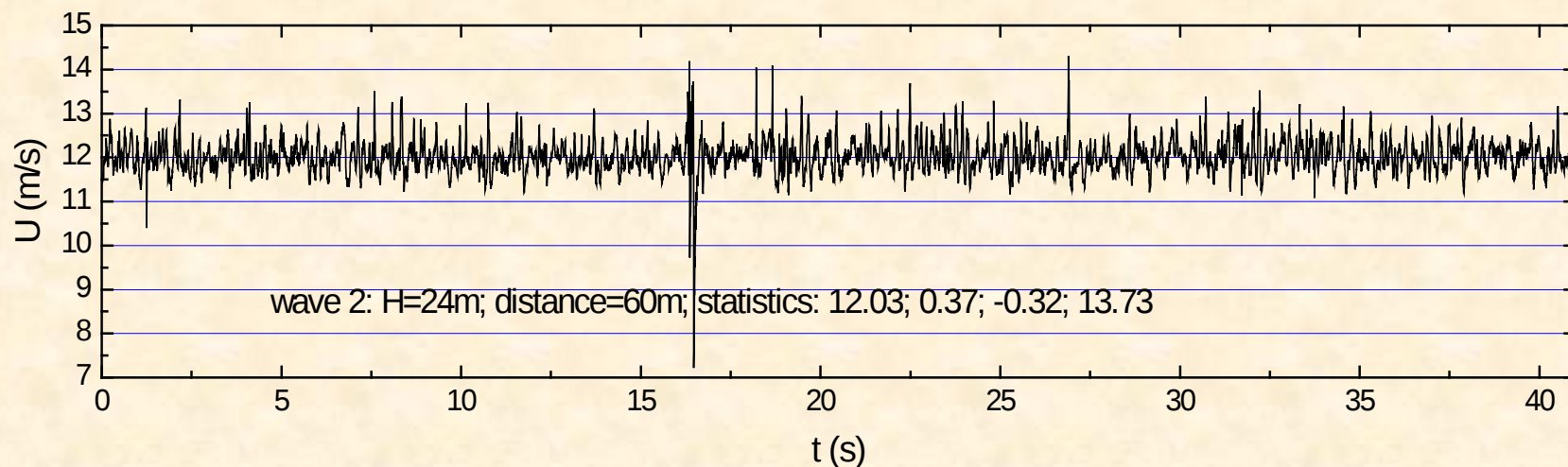


三维脉动
风速仪流
场测试



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3. 测速试验



典型脉动风速时程

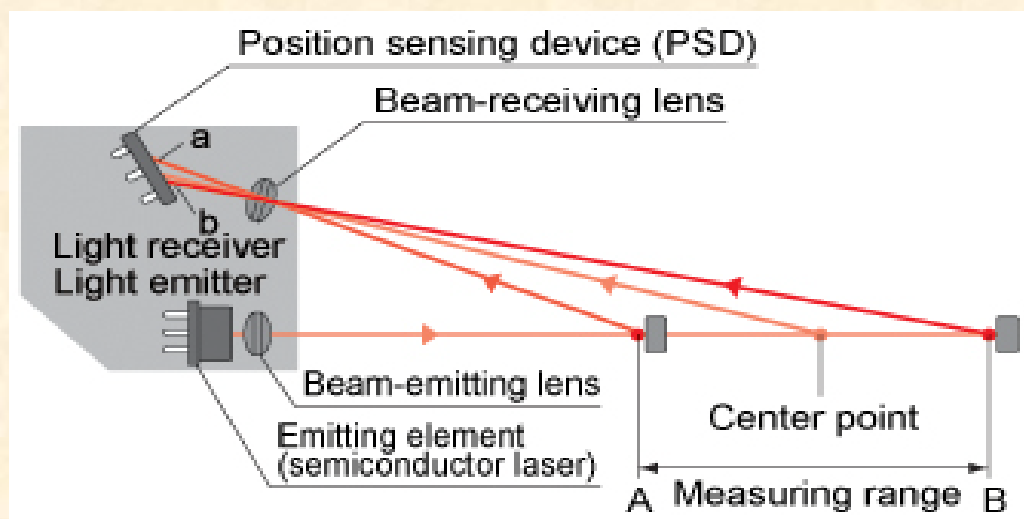


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4. 测振试验



激光位移计



激光位移计基本测试原理示意图



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4. 测振试验

Class 1

Range: $50 \pm 10 \text{ mm}$ $1.969 \pm 0.394 \text{ in}$
 Resolution: $5 \mu\text{m}$ 1.969 mil
 Range: $50 \pm 10 \text{ mm}$ $1.969 \pm 0.394 \text{ in}$
 Resolution: $5 \mu\text{m}$ 1.969 mil
 Range: $80 \pm 20 \text{ mm}$ $3.150 \pm 0.787 \text{ in}$
 Resolution: $20 \mu\text{m}$ 0.787 mil
 Range: $130 \pm 50 \text{ mm}$ $5.118 \pm 1.969 \text{ in}$
 Resolution: $100 \mu\text{m}$ 3.937 mil

2 m 6.562 ft.

(ANR1150)
(ANR1151)
(ANR1182)
(ANR1115)

Class 2

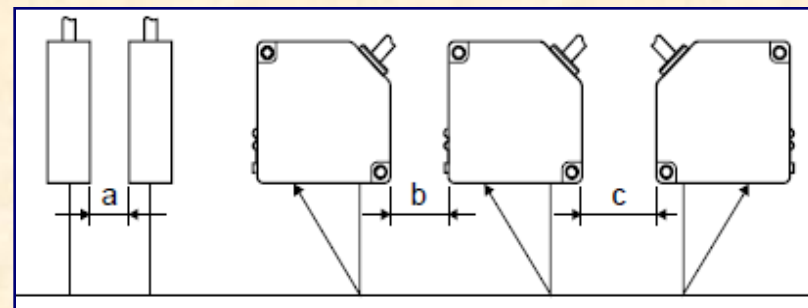
Range: $50 \pm 10 \text{ mm}$ $1.969 \pm 0.394 \text{ in}$
 Resolution: $1 \mu\text{m}$ 0.039 mil
 Range: $50 \pm 10 \text{ mm}$ $1.969 \pm 0.394 \text{ in}$
 Resolution: $1 \mu\text{m}$ 0.039 mil
 Range: $80 \pm 20 \text{ mm}$ $3.150 \pm 0.787 \text{ in}$
 Resolution: $4 \mu\text{m}$ 0.157 mil
 Range: $130 \pm 50 \text{ mm}$ $5.118 \pm 1.969 \text{ in}$
 Resolution: $20 \mu\text{m}$ 0.787 mil
 Range: $250 \pm 150 \text{ mm}$ $9.843 \pm 5.906 \text{ in}$
 Resolution: $150 \mu\text{m}$ 5.906 mil

0.5 m 1.640 ft

1.5 m 4.921 ft

Relay connector Intermediate cable

(ANR1250)
(ANR1251)
(ANR1282)
(ANR1215)
(ANR1226)



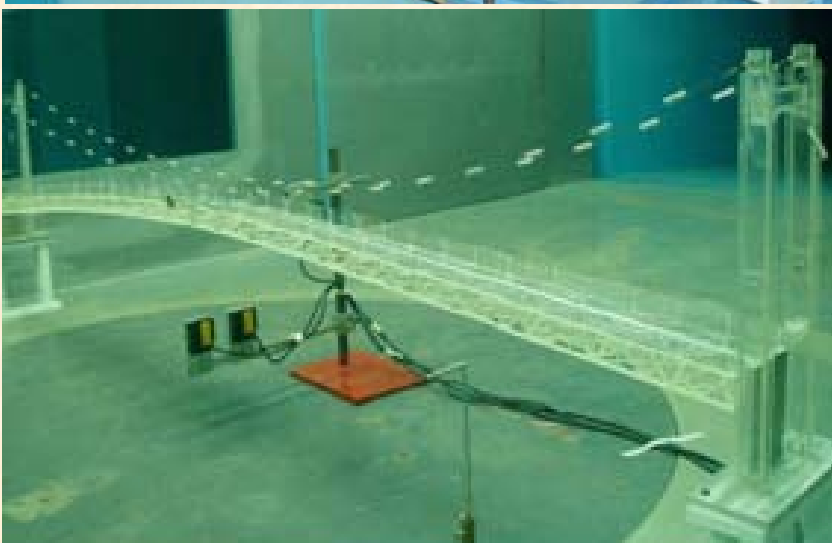
Sensor model No.	Units (mm in)		
	a	b	c
ANR1150	40 1.575	20 0.787	70 2.756
ANR1151			
ANR1182	50 1.969	60 2.362	110 4.331
ANR1115	80 3.150	100 3.937	150 5.906
ANR1250	50 1.969	40 1.575	90 3.543
ANR1251			
ANR1282	80 3.150	80 3.150	130 5.118
ANR1215	120 4.724	140 5.512	190 7.480
ANR1226	210 8.268	350 13.780	400 15.748

不同型号激光位移计相关参数与临近安装时的距离要求



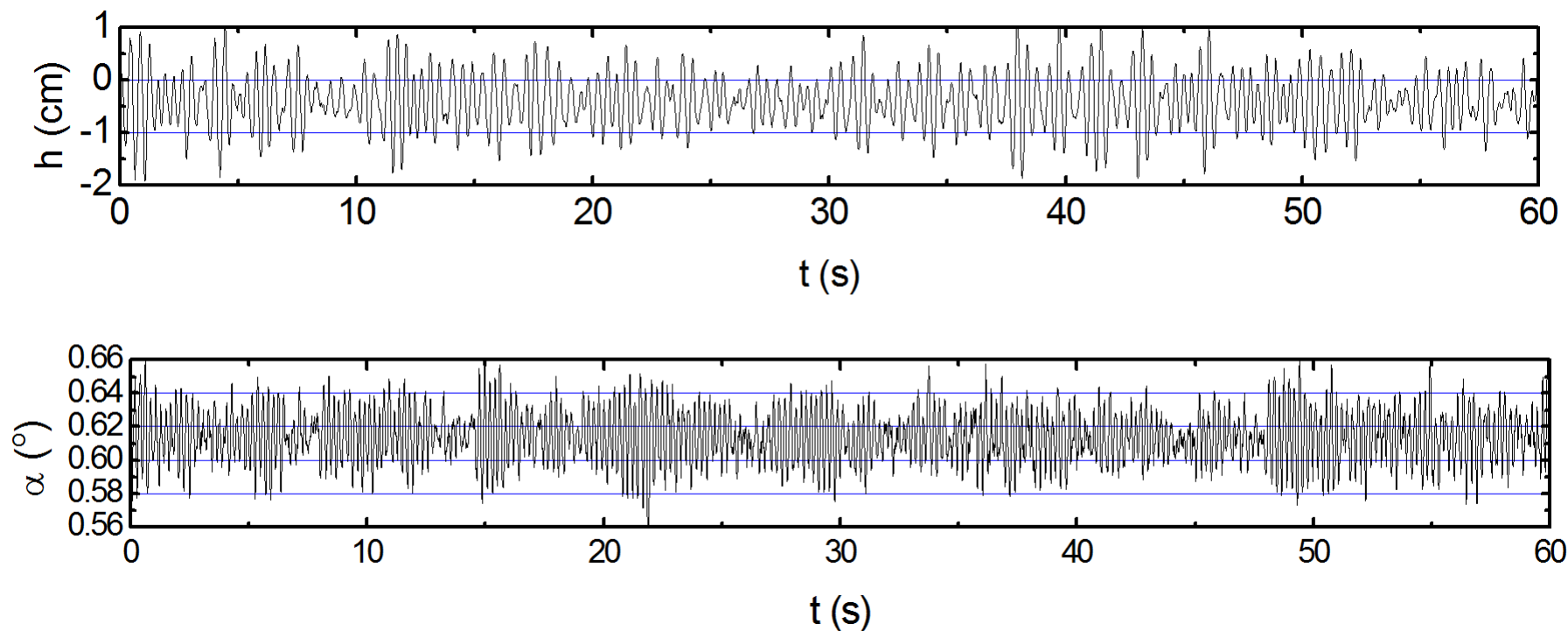
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4. 测振试验





4. 测振试验



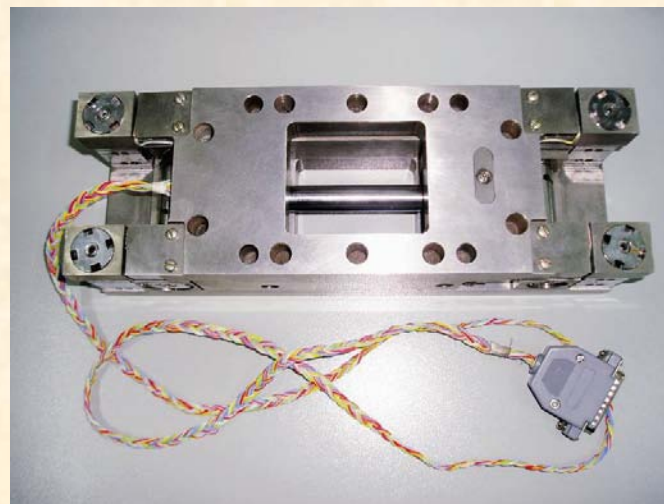
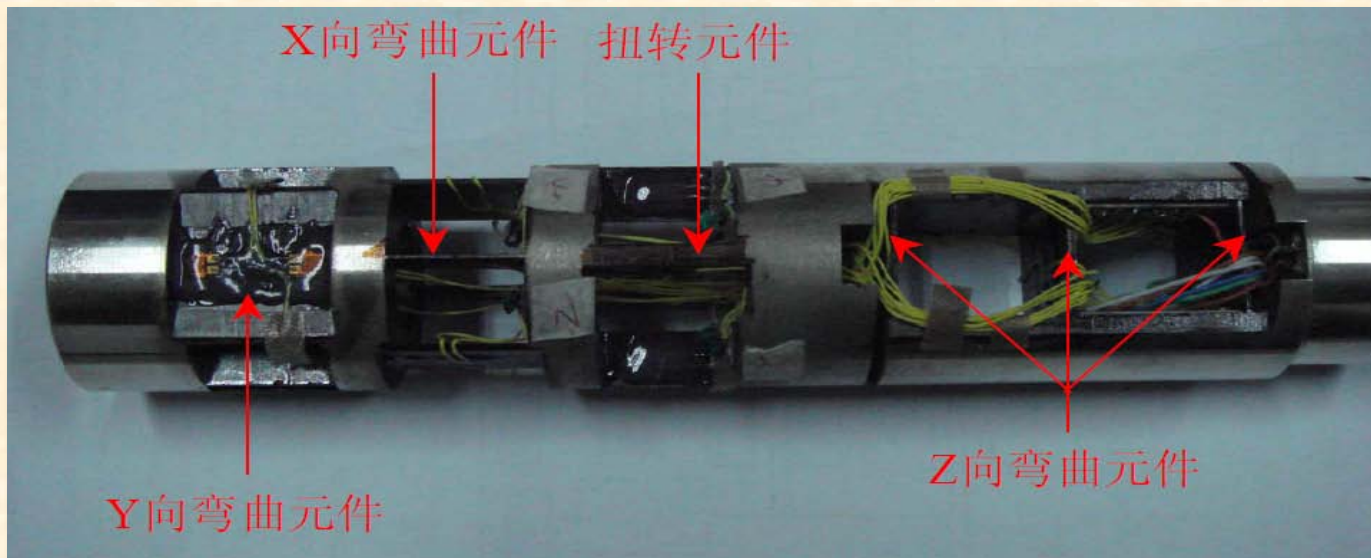
模型振动位移时程



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5. 测力试验

典型测力天平

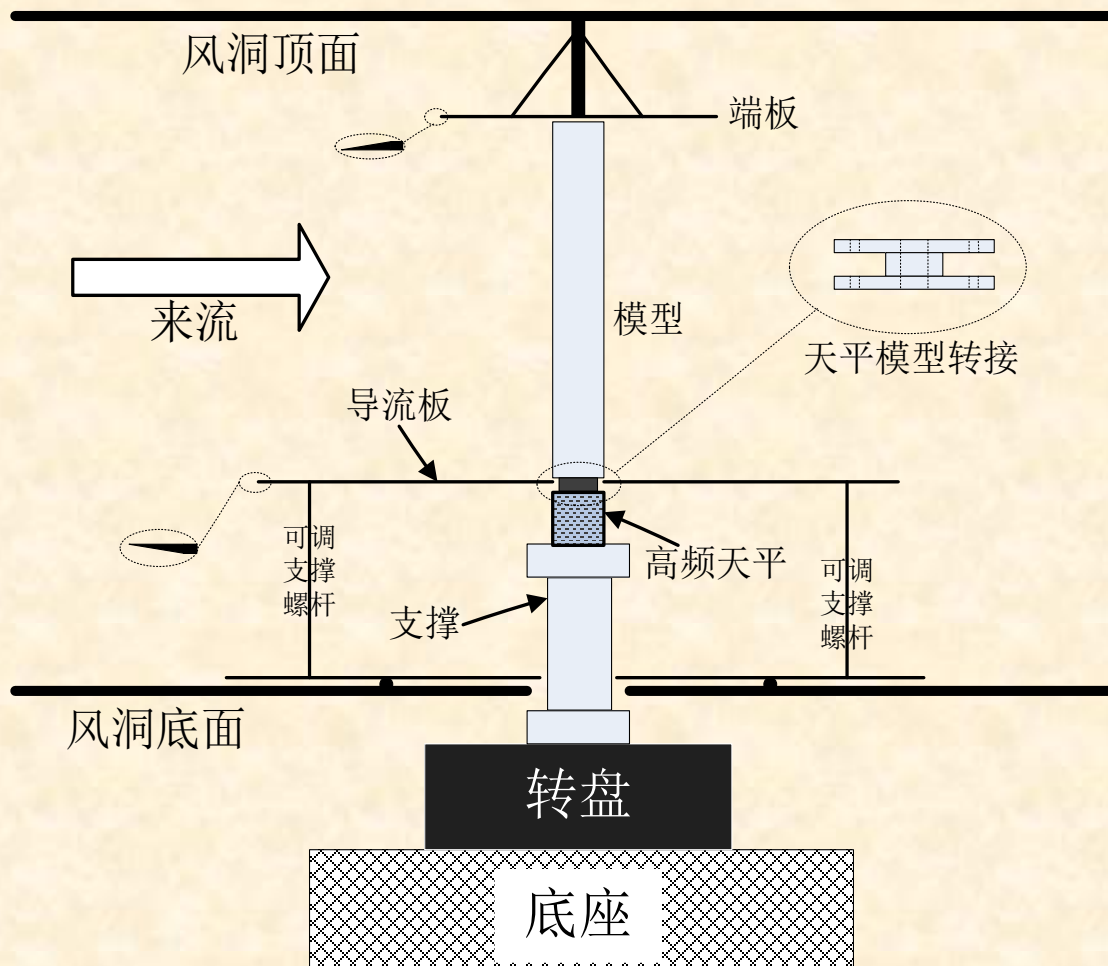




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5. 测力试验

风洞测力试验示意图





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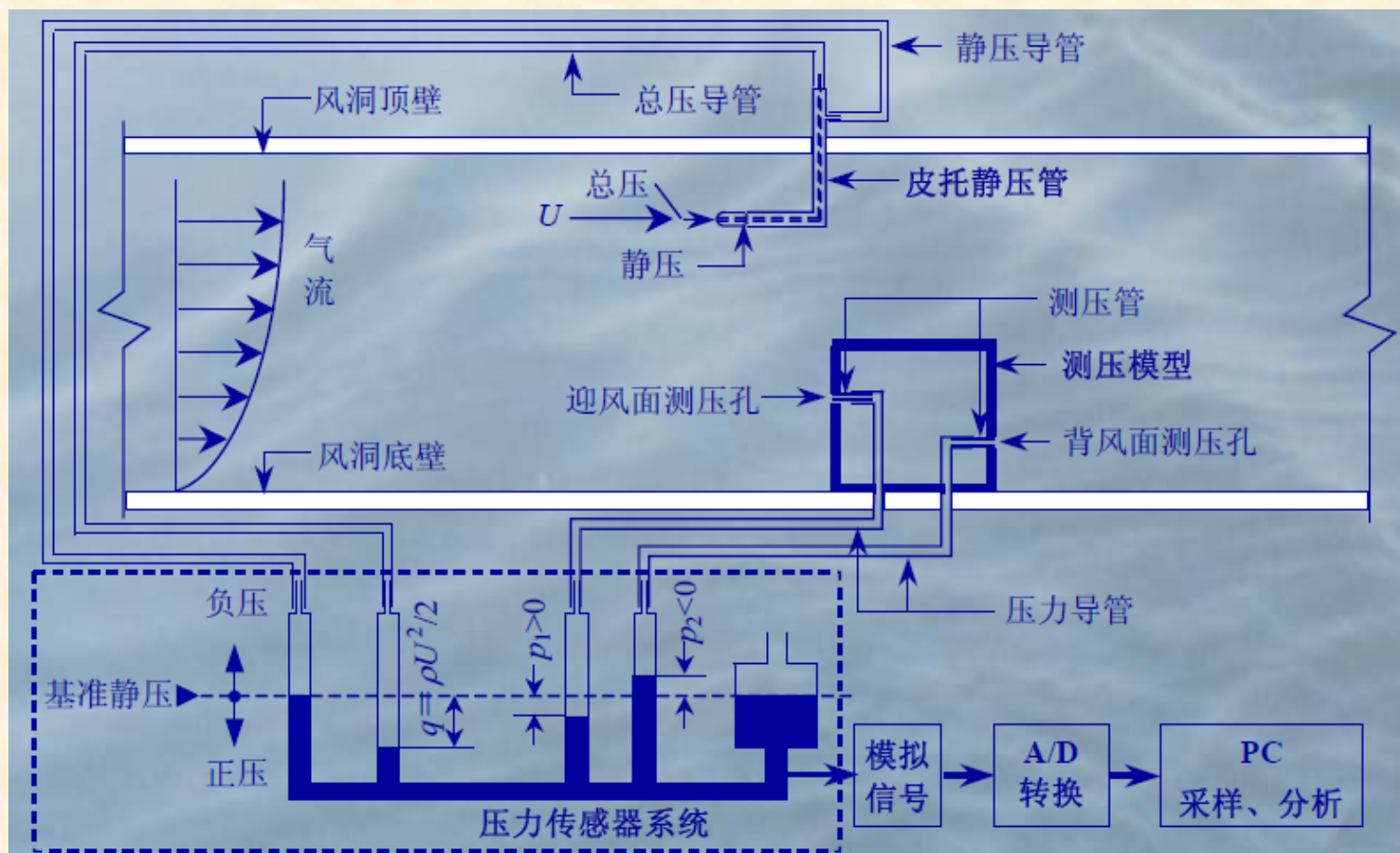
6. 测压试验



电子压力扫描阀



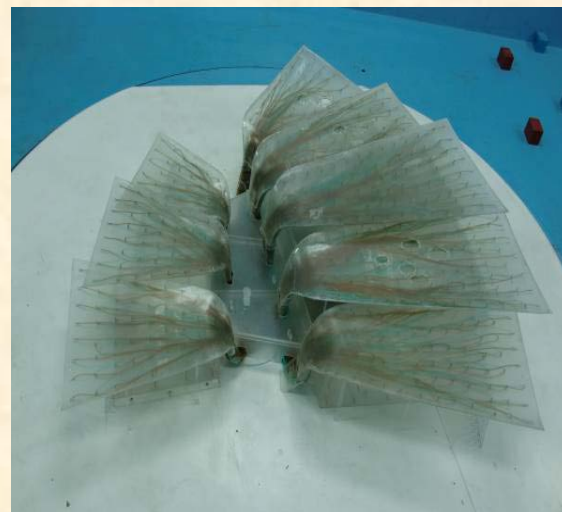
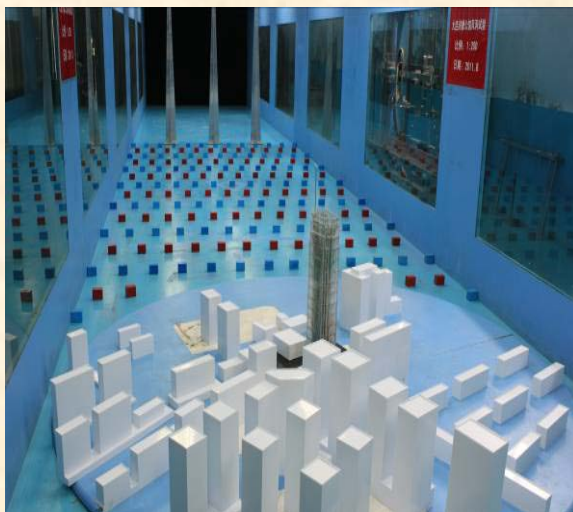
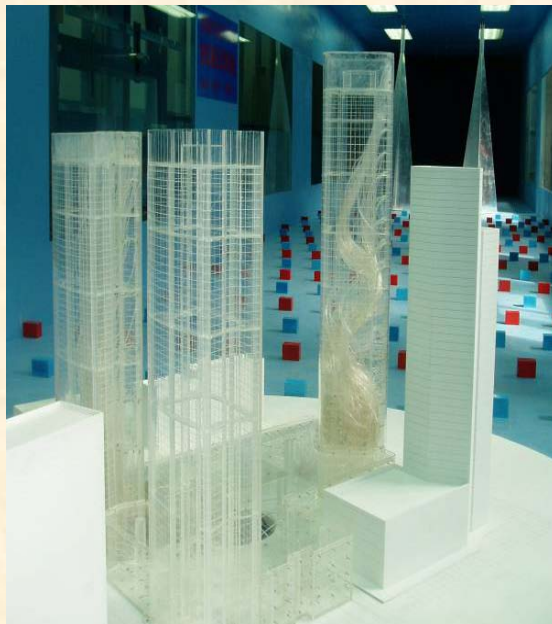
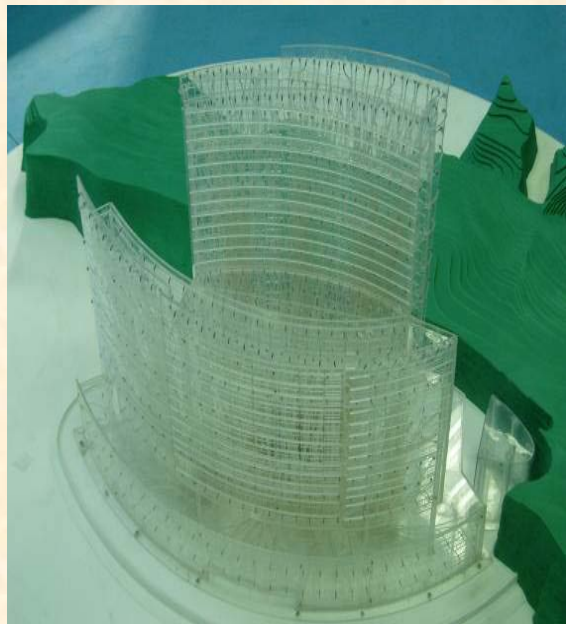
6. 测压试验



风洞测压试验流程示意图

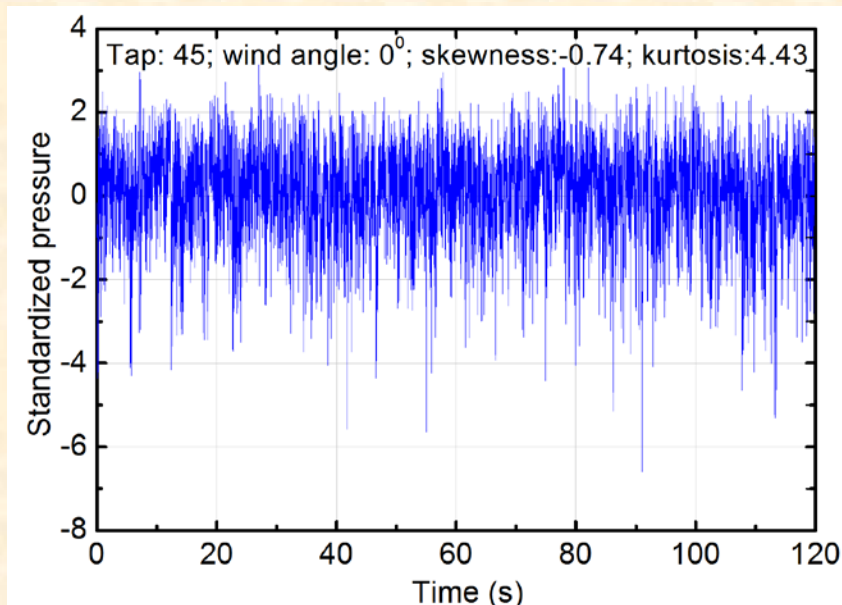


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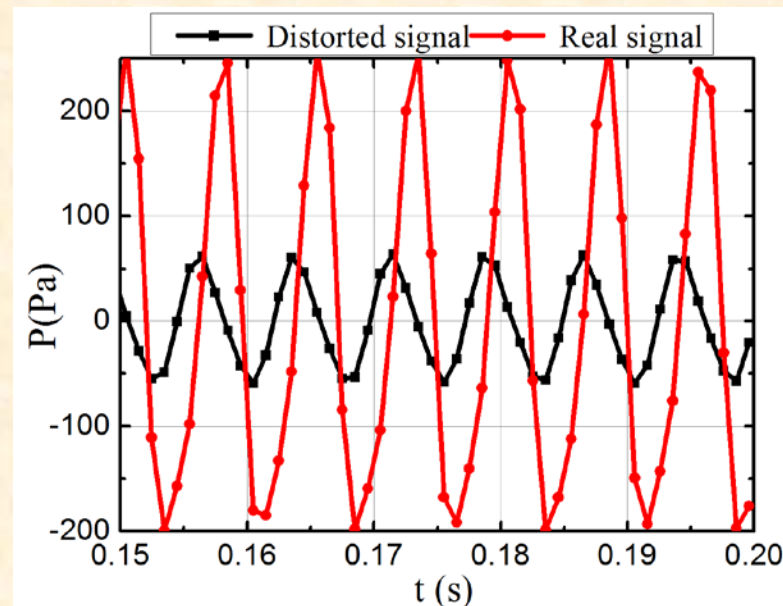




6. 测压试验



标准化的脉动风压时程



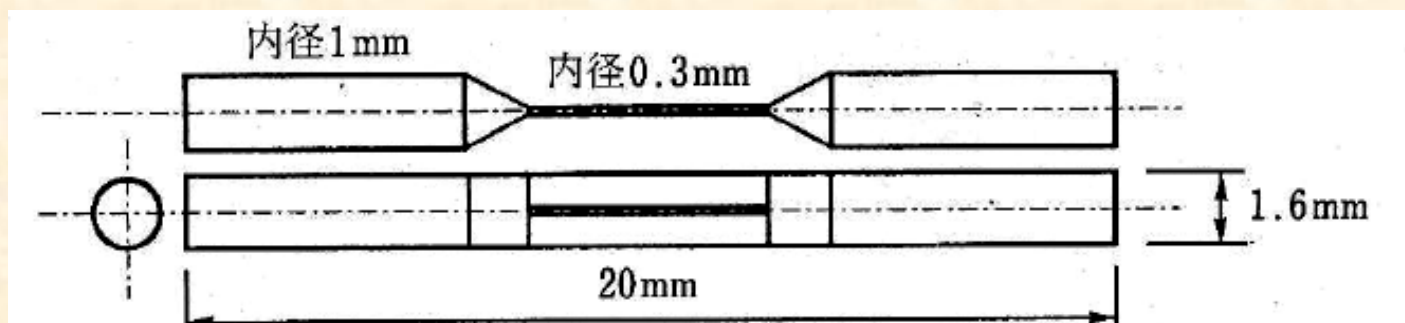
实测风压与真实风压对比

对于测压试验，需要注意管道信号畸变问题：

(1) 产生驻波；(2) 产生管腔共振。

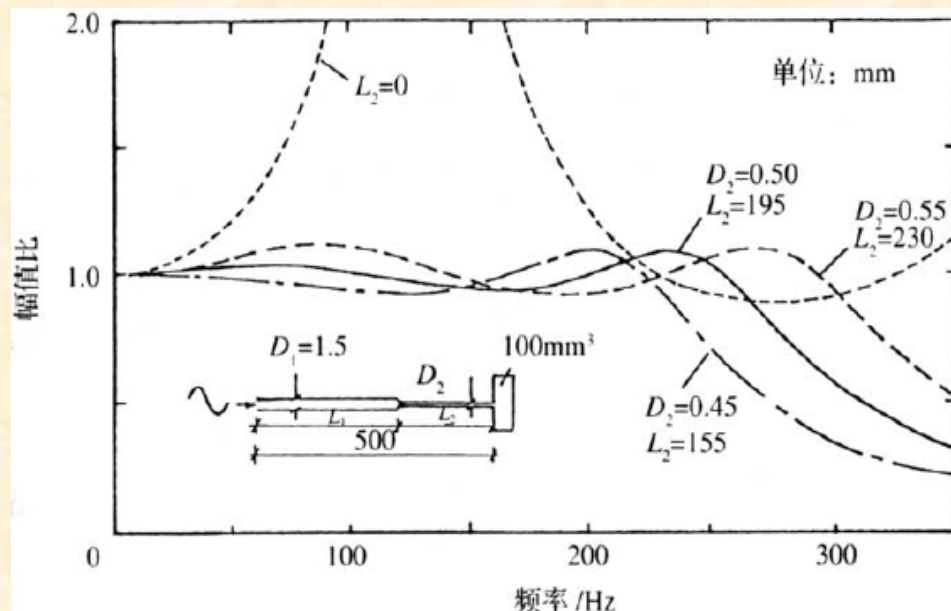


6. 测压试验



压扁管示意图

压扁管法



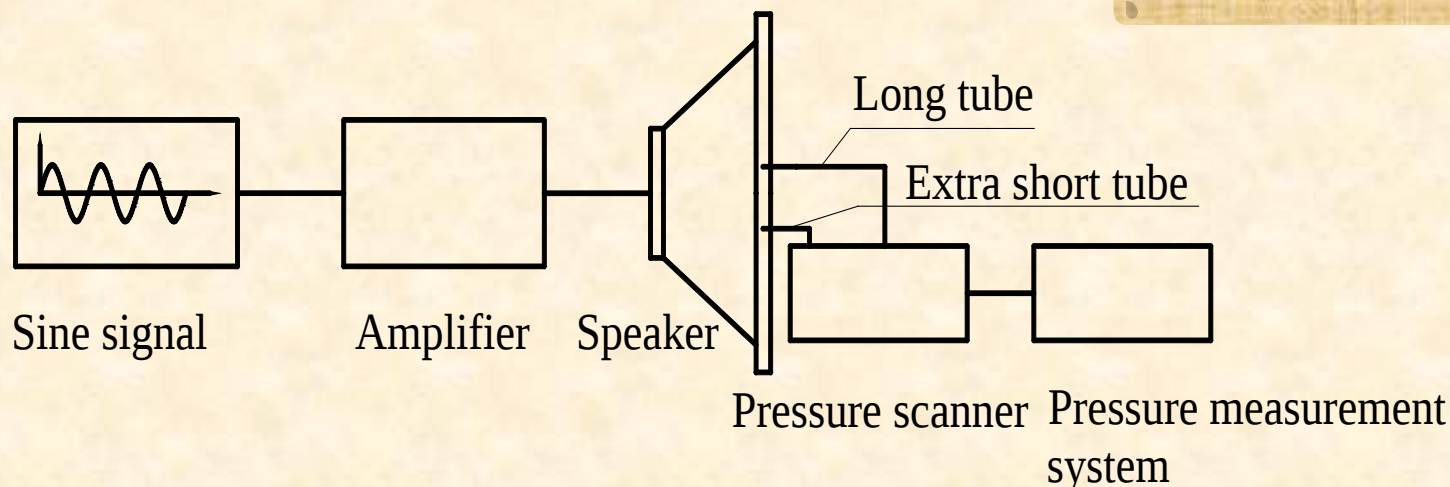
不同条件下压力幅值比



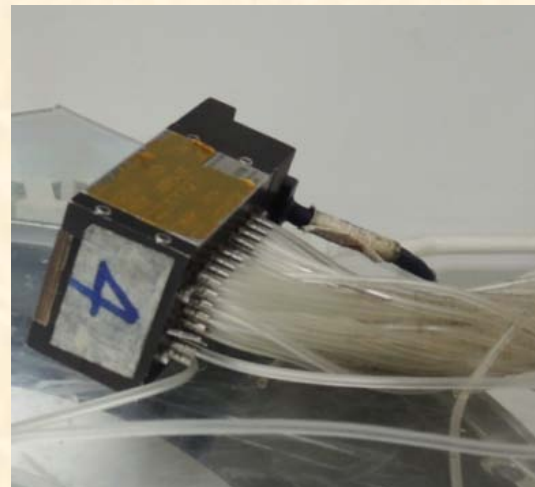
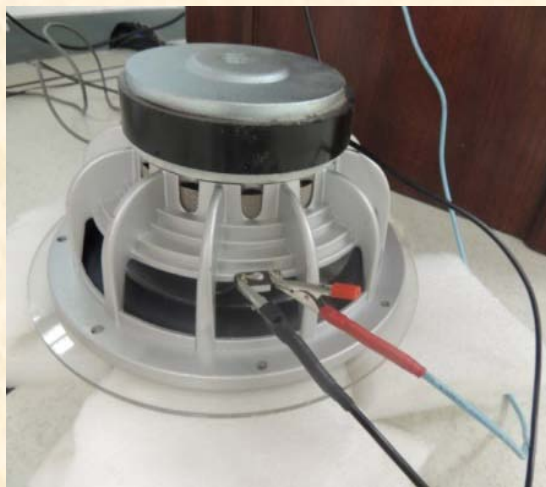
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6. 测压试验

理论修正方法



压强标定系统示意图与压强标定设备





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6. 测压试验

(1) 管道内径 : 0.9mm ;

(2) 管道长度 (cm) :

30, 40, 50, 60, 70, 80, 90, 100, 120, 150, 180, 200 ;

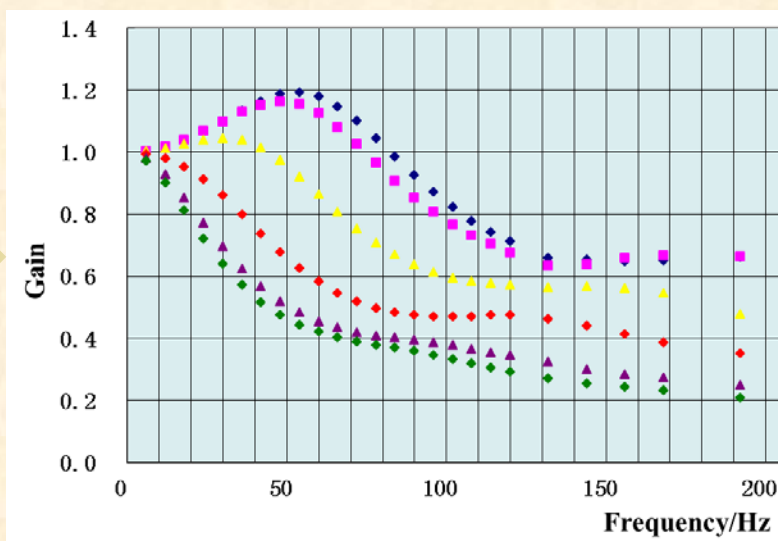
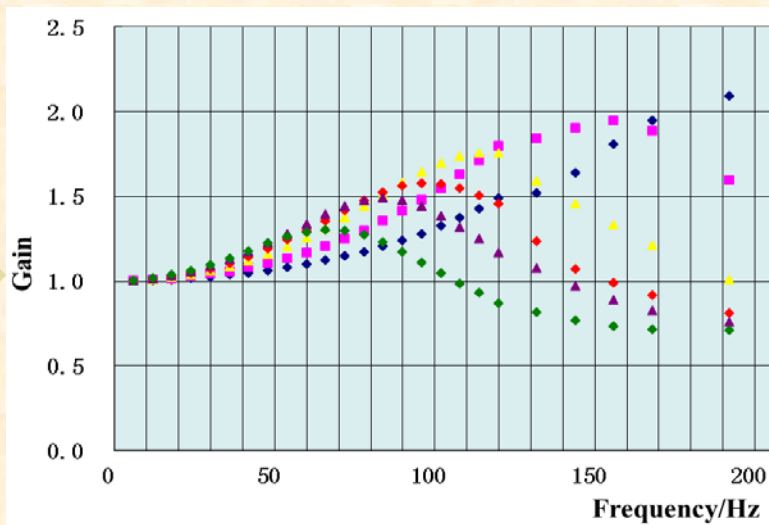
(3) 输入正弦信号 , 频率分别为 :

**5, 10, 15...100, 110, 120, 130, 140, 160, 180, 200,
220, 240, 260, 280, 320, 340 Hz。**



6. 测压试验

不同条件下压力幅值比

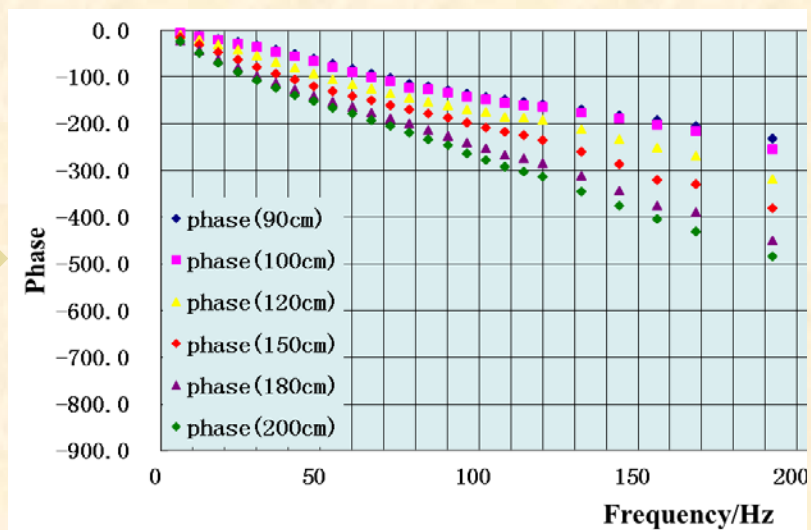
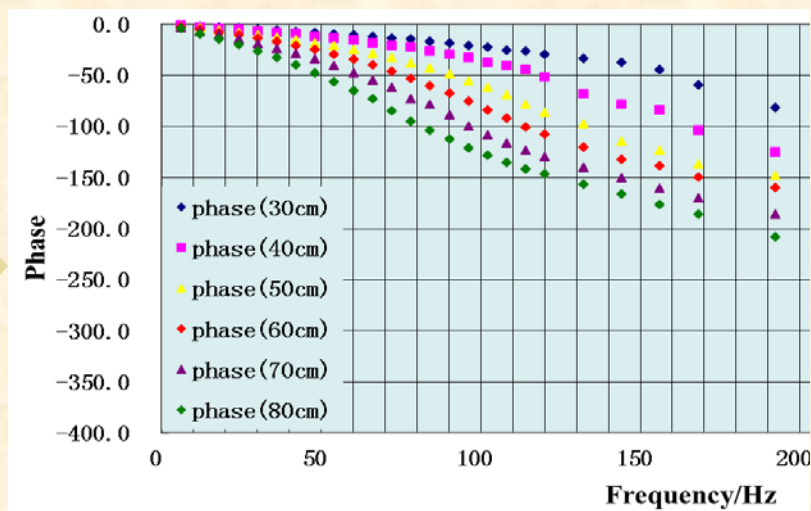




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6. 测压试验

不同条件下信号相位差

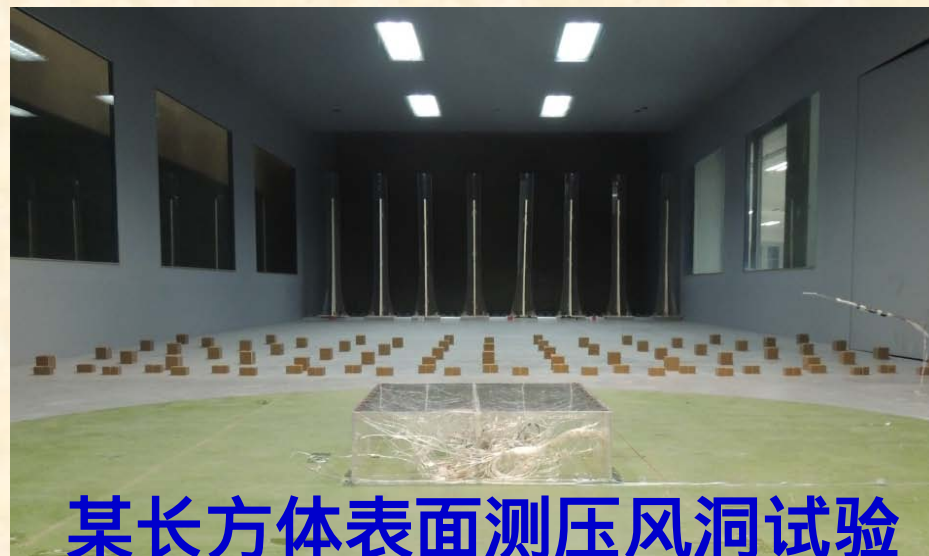
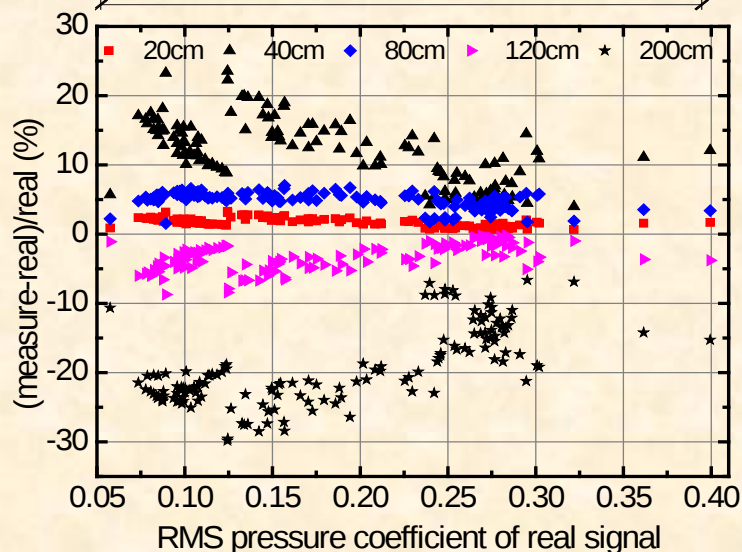
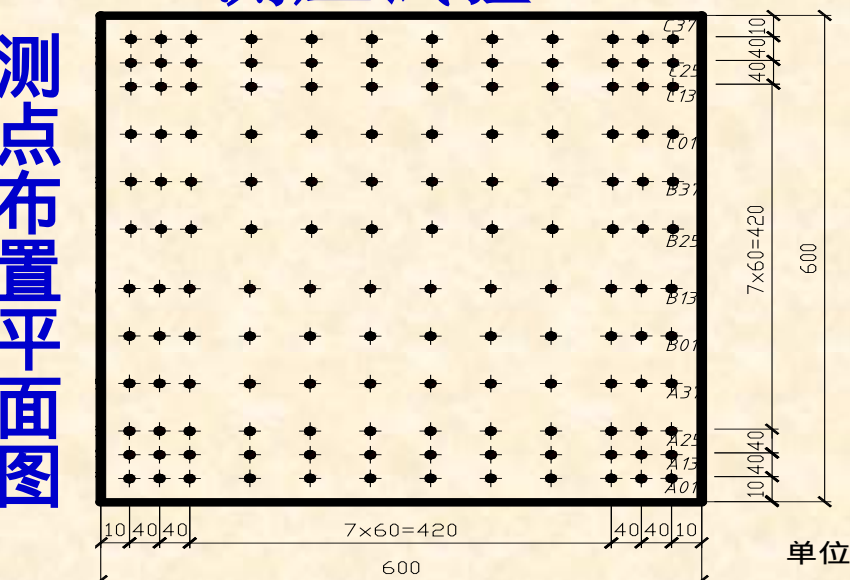




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6. 测压试验

测点布置平面图

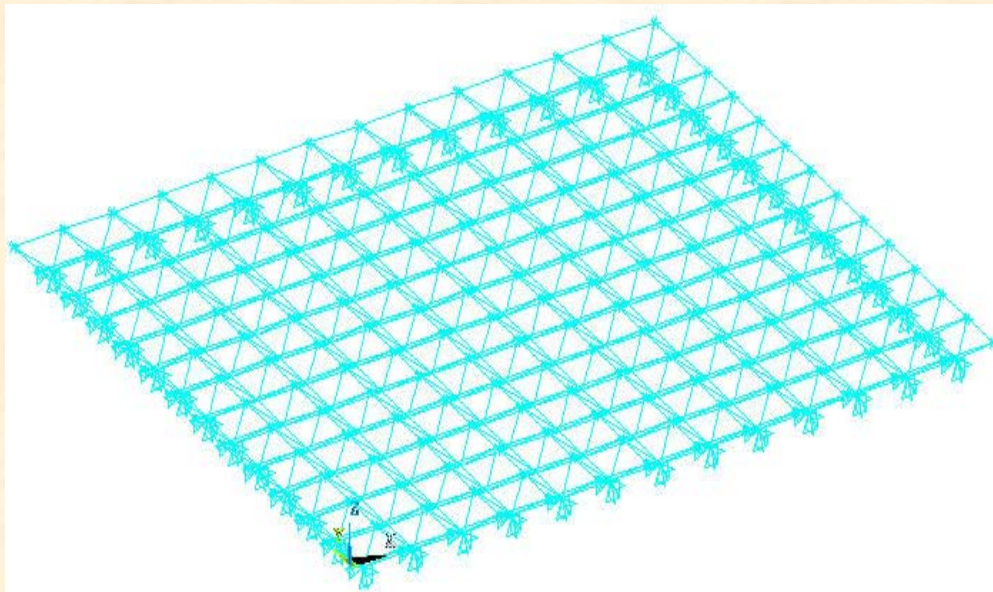


某长方体表面测压风洞试验

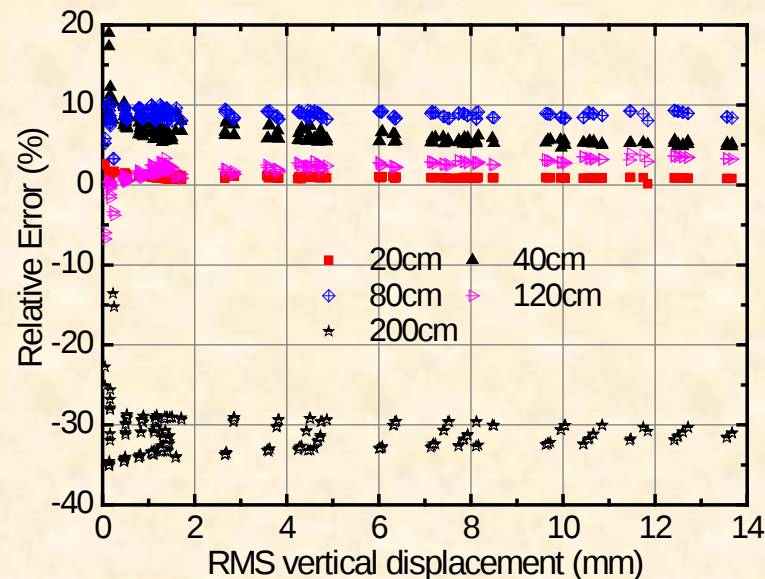
不同管长条件下风压
系数脉动值相对误差



6. 测压试验



某桁架结构空间有限元模型
(阻尼比: 2% ; 跨径: 40m)



不同条件下竖弯位移
标准差相对误差



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Qs ?

See you



Thank you