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EVALUATION OF A VORTEX TUBE COOLER.(U)
APR 77 A H CHADWICK
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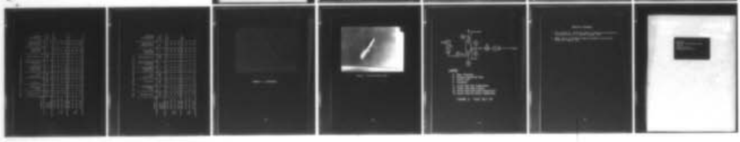

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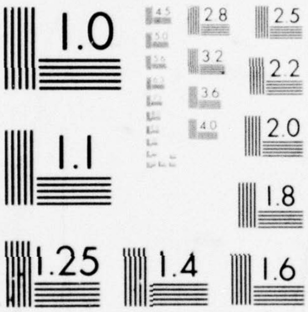

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The Navy Clothing and Textile Research Facility (NCTRF) tested a commercial vortex tube cooler for personnel air conditioning to accumulate data for possible future applications. The vortex cooler had six interchangeable nozzles which allowed various cold flow ranges from 7 to 24 cubic feet per minute. The unit was tested in each configuration to determine the various available flows and temperatures. When the unit was supplied with air at a nominal 95 psig, its temperature fell 40, 49, 51, 56, 47, and 52 F with flows

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of 21, 16, 12, 9, 8, and 7 cubic feet per minute, respectively, at sea level pressures. Based on the amount of cooling available, we concluded that only the first four configurations would provide ample cooling for suited personnel (U).

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EVALUATION OF A VORTEX TUBE COOLER

INTRODUCTION

The Navy Clothing and Textile Research Facility (NCTRF) has conducted a series of performance tests on a commercial vortex tube cooler to obtain performance data for future applications for our own use in personnel cooling. The vortex tube was instrumented in the laboratory and numerous performance tests were run. Of the six configurations tested, four were found to have suitable characteristics for use in manned cooling applications. The purpose of this report is to present the performance data derived from the tests.

DESCRIPTION OF EQUIPMENT

A vortex tube is a device which divides compressed air into two streams--one heated and the other cooled from the original inlet temperature. This separation is accomplished with no moving parts, and only the compressed air as an energy source. Compressed air systems of 80 to 100 psig pressure, typical of shipboard or industrial installations, are sufficient to power the device.

The vortex tube is shown in Figure 1. The air inlet is at the right side of the tube, the cold air outlet at the bottom, and the control valve at the top. The tube, which weighs 9 ounces, is 10¼ inches long and 1 1/8 inches in diameter excluding the carrying handle. The device can be used for cooling equipment or providing portable personal cooling for individuals in hot environments where the compressed air supply is available through a flexible air hose.

Vortex tubes have been on the market for a number of years. Since NCTRF has a continuing interest in personal heating and cooling devices, we decided to test a vortex tube in our laboratory to obtain performance data on gas inlet pressures, flows, and temperatures, and gas outlet flows and temperatures available. These data are to be held for possible future applications in personal or equipment cooling.

PROCEDURES

The vortex tube selected offered a choice of three nominal inlet flows--11, 15, and 25 SCFM. Each of these flows gave the option of a low flow of very cold outlet air or a higher flow of moderately cold air. Thus, there were six separate nozzles available.

Each nozzle configuration was run at 100 psig and 80 psig inlet pressure. At each of these pressures, the compressed air was supplied at 80°F and 125°F. At each of the conditions of temperature and pressure, the vortex tube was run with its control valve in the full open position and in the position which produced approximately one-half of the temperature drop which had occurred for the full open position.

Figure 2 shows the test set-up. The compressed air supply had a maximum delivery pressure of 100 psig at the compressor, but at the higher flows (30 SCFM) line losses cut pressure to 93 psig in the laboratory. The compressor provided dry air with a dew point of less than 0°F.

The inlet flow was measured by a 0 to 50 SCFM mass flowmeter which read out directly, with no conversions required. The cold-side outlet flow was measured by a 0 to 40 SCFM variable area flowmeter, which was calibrated against the mass flowmeter. The hot-side flow was taken as the difference between the two. Temperatures between 0 and 200°F were recorded on a multipoint temperature recorder with copper-constantin thermocouples; temperatures which exceeded the range limit of the recorder (200°F) were measured with a dial thermometer. The thermocouples or thermometer were placed in the airstreams at the vortex tube outlets by inserting them through the walls of the soft plastic tubing used for routing the discharge air. The inlet pressure was measured with a 0 - 100 psig gauge at the item inlet; both outlet pressures were essentially atmospheric. For operations at 100 psig nominal, the throttling valve was left full open and the inlet pressures accepted as limited by the line losses. For operation at 80 psig, the throttling valve was manually positioned to produce the 80 psig inlet pressure.

At every test condition, the temperature was allowed to stabilize on the recorder before final readings were taken.

RESULTS

Initially, the vortex tube was run to determine the valve setting which would yield half of the total temperature decrease available with the valve full open. (The valve required almost four complete turns to change from closed to open.) One quarter of one turn to the open position was required to give the desired temperature drop. The positioning of the valve produced the following temperature drops:

Valve Position	Air Temperature Drop
1/4 turn open	19°F
1/2 turn open	31°F
3/4 turn open	34°F
1 turn open	35°F
3 3/4 turn open (full open)	37°F

The above readings were for the 25H nozzle, but the other nozzles behaved similarly.

The 1/4 turn open position and the full open position settings were then established for each of the test conditions. The results are listed in Tables I, II and III. The cooling capacities for the various nozzle configurations may be summarized as follows for compressed air delivered at 100 psig and 80°F:

nozzle 25 H - 22.2 SCFM air cooled 41°F below inlet temperature
nozzle 25 L - 17.9 SCFM air cooled 49°F below inlet temperature
nozzle 15 H - 13.2 SCFM air cooled 51°F below inlet temperature
nozzle 15 L - 10.6 SCFM air cooled 56°F below inlet temperature
nozzle 11 H - 9.0 SCFM air cooled 47°F below inlet temperature
nozzle 11 L - 8.2 SCFM air cooled 52°F below inlet temperature

DISCUSSION OF RESULTS

For purposes of providing personal cooling it is necessary to dissipate heat loads in the range of 650 BTU/hr for an inactive standing male and 1000 BTU/hr for one doing moderate work (1). By assuming a possible temperature increase to 80°F saturated while passing over the body, the 11 H orifice could produce 770 BTU/hr of latent cooling and 451 BTU/hr of sensible cooling. The 11 L orifice could produce under similar circumstances 693 BTU/hr latent and 445 BTU/hr sensible cooling. The 15 H orifice could give 1118 latent and 716 sensible BTU/hr while the 15 L orifice could give 898 latent and 629 sensible BTU/hr. The 25 H orifice could provide 1880 latent and 886 sensible BTU/hr, and the 25 L orifice could furnish 1516 latent and 879 sensible BTU/hr.

The preceding values could occur with the control valve full open and with a 100 psig nominal inlet pressure. While any of the orifices could provide a minimum of cooling, the 11 CFM orifices seem to be marginal to unacceptable for man cooling applications when external heat losses are taken into account. The 15 CFM orifices could handle moderate load activities while the 25 CFM orifices could handle the heavy workload activities.

The small size and weight of the device make it an attractive means of providing a personal cooling capability when the source of compressed air is readily available. The device is relatively inefficient, however. For example, when used as a cooling medium, the 25 H orifice full open at 100 psig is only 7.5 percent efficient. This figure is based upon the amount of air cooled and the horsepower required to do it. For the 25 CFM orifices, a 5 HP compressor would be required, for the 15 CFM orifices, a 3½ HP compressor, and for the 11 CFM orifices, a 2½ HP compressor (2).

CONCLUSIONS

Since the purpose of the experiment was to obtain performance data for future use, no definite level of acceptance was expected or established. The device functioned properly. The relative insensitivity of the built-in adjustable valve (1/4 of 1 revolution for one half of the available temperature drop) and the fact that it frequently was too hot to handle would indicate that the concept of an adjustable capability should be abandoned and that the vortex tube be used in the full open position.

Table I. Performance Data from Orifice 25 H

Orifice 25 H		Inlet Pressure	Inlet Temperature	Inlet Flow	Cold Outlet Flow	Cold Outlet Temperature	Cold Flow Temperature Drop	Hot Outlet Flow	Hot Outlet Temperature	Hot Flow Temperature Rise	Refrigeration Achieved
	Control Valve Position	PSIG	°F	SCFM	SCFM	°F	°F	SCFM	°F	°F	BTU/hr
100 psig	Full Open	94	82	27.0	22.2	41	41	4.8	235	153	983
	¼ Turn Open	94	82	25.5	22.5	62	32	3.0	215	133	
	¼ Turn Open	95	125	28.5	20.5	96	29	8.0	330	205	
	Full Open	95	125	29.0	19.2	78	47	9.8	280	155	
80 psig	Full Open	80	81	23.0	19.5	44	37	3.5	240	159	779
	¼ Turn Open	80	81	22.5	19.6	63	18	2.9	215	134	
	¼ Turn Open	80	125	25.0	17.8	96	29	7.2	310	185	
	Full Open	80	125	25.5	16.7	80	45	8.8	290	165	

Table I. Performance Data from Orifice 25 L

	Orifice 25 L	Inlet Pressure	Inlet Temperature	Inlet Flow	Cold Outlet Flow	Cold Outlet Temperature	Cold Flow Temperature Drop	Hot Outlet Flow	Hot Outlet Temperature	Hot Flow Temperature Rise	Refrigeration Achieved
	Control Valve Position	PSIG	°F	SCFM	SCFM	°F	°F	SCFM	°F	°F	BTU/hr
100 psig	Full Open	95	81	24.5	17.9	32	49	6.6	192	111	947
	¼ Turn Open	96	81	22.5	18.5	60	21	4.0	174	93	
	¼ Turn Open	96	125	26.5	13.4	87	38	13.1	290	165	
	Full Open	96	124	27.5	15.7	68	56	11.8	250	126	
80 psig	Full Open	80	81	21.0	15.6	34	47	5.4	192	111	792
	¼ Turn Open	80	81	19.5	16.0	61	20	3.5	173	92	
	¼ Turn Open	80	124	23.0	14.5	87	37	8.5	285	161	
	Full Open	80	124	25.0	13.6	69	55	11.4	245	121	

Table II. Performance Data from Orifice 15 H

	Orifice 15 H	Inlet Pressure	Inlet Temperature	Inlet Flow	Cold Outlet Flow	Cold Outlet Temperature	Cold Flow Temperature Drop	Hot Outlet Flow	Hot Outlet Temperature	Hot Flow Temperature Rise	Refrigeration Achieved
	Control Valve Position	PSIG	^oF	SCFM	SCFM	^oF	^oF	SCFM	^oF	^oF	BTU/hr
100 psig	Full Open	98	78	16.5	13.2	27	51	3.3	230	152	727
	¼ Turn Open	98	79	16.0	14.1	47	32	1.9	270	191	
	¼ Turn Open	98	125	17.0	11.8	89	36	5.2	335	210	
	Full Open	98	124	17.5	10.9	66	58	6.6	295	171	
80 psig	Full Open	80	78	14.0	10.8	31	47	3.2	240	162	548
	¼ Turn Open	80	78	13.5	11.5	49	29	2.0	275	197	
	¼ Turn Open	80	125	14.0	9.9	88	37	4.1	320	195	
	Full Open	80	125	15.0	9.6	70	55	5.4	305	180	

Table II. Performance Data from Orifice 15 L

	Orifice 15 L	Inlet Pressure	Inlet Temperature	Inlet Flow	Cold Outlet Flow	Cold Outlet Temperature	Cold Flow Temperature Drop	Hot Outlet Flow	Hot Outlet Temperature	Hot Flow Temperature Rise	Refrigeration Achieved
	Control Valve Position	PSIG	°F	SCFM	SCFM	°F	°F	SCFM	°F	°F	BTU/hr
100 psig	Full Open	98	78	15.5	10.6	22	56	4.9	191	113	641
	¼ Turn Open	99	78	14.5	10.5	53	25	4.0	158	80	
	¼ Turn Open	98	124	15.5	8.4	95	29	7.1	215	91	
	Full Open	98	125	16.5	9.1	60	65	7.4	255	130	
80 psig	Full Open	80	78	13.0	9.2	26	52	3.8	192	86	517
	¼ Turn Open	80	78	12.0	8.7	55	23	3.3	153	75	
	¼ Turn Open	80	124	13.0	7.5	93	31	5.5	220	96	
	Full Open	80	125	14.0	7.8	61	64	6.2	250	125	

Table III. Performance Data from Orifice 11 H

	Orifice 11 H	Inlet Pressure	Inlet Temperature	Inlet Flow	Cold Outlet Flow	Cold Outlet Temperature	Cold Flow Temperature Drop	Hot Outlet Flow	Hot Outlet Temperature	Hot Flow Temperature Rise	Refrigeration Achieved
	Control Valve Position	PSIG	°F	SCFM	SCFM	°F	°F	SCFM	°F	°F	BTU/hr
100 psig	Full Open	98	78	12.0	9.0	31	47	3.0	235	157	457
	¼ Turn Open	98	78	11.5	9.9	43	35	1.6	250	172	
	¼ Turn Open	98	125	13.5	8.3	92	33	5.2	250	125	
	Full Open	98	125	13.5	7.6	68	57	5.9	300	175	
80 psig	Full Open	80	78	10.5	7.5	36	42	3.0	240	162	340
	¼ Turn Open	80	78	10.0	8.1	51	27	1.9	250	172	
	¼ Turn Open	80	125	11.5	6.8	91	34	4.7	250	125	
	Full Open	80	124	11.0	6.8	71	53	4.2	290	166	

Table III. Performance Data from Orifice 11 L

	Orifice 11 L	Inlet Pressure	Inlet Temperature	Inlet Flow	Cold Outlet Flow	Cold Outlet Temperature	Cold Flow Temperature Drop	Hot Outlet Flow	Hot Outlet Temperature	Hot Flow Temperature Rise	Refrigeration Achieved
	Control Valve Position	PSIG	°F	SCFM	SCFM	°F	°F	SCFM	°F	°F	BTU/hr
100 psig	Full Open	98	79	12.0	8.2	27	52	3.8	199	120	461
	¼ Turn Open	98	79	11.5	8.5	53	26	3.0	168	89	
	¼ Turn Open	98	124	13.0	7.1	93	31	5.9	220	96	
	Full Open	98	125	14.0	7.3	63	62	6.7	260	135	
80 psig	Full Open	80	78	10.0	7.1	31	47	2.9	205	127	360
	¼ Turn Open	80	79	10.0	7.7	47	32	2.3	210	131	
	¼ Turn Open	80	124	11.0	6.1	89	35	4.9	220	96	
	Full Open	80	125	12.0	6.0	67	58	6.0	260	135	

APPENDIX A. ILLUSTRATIONS

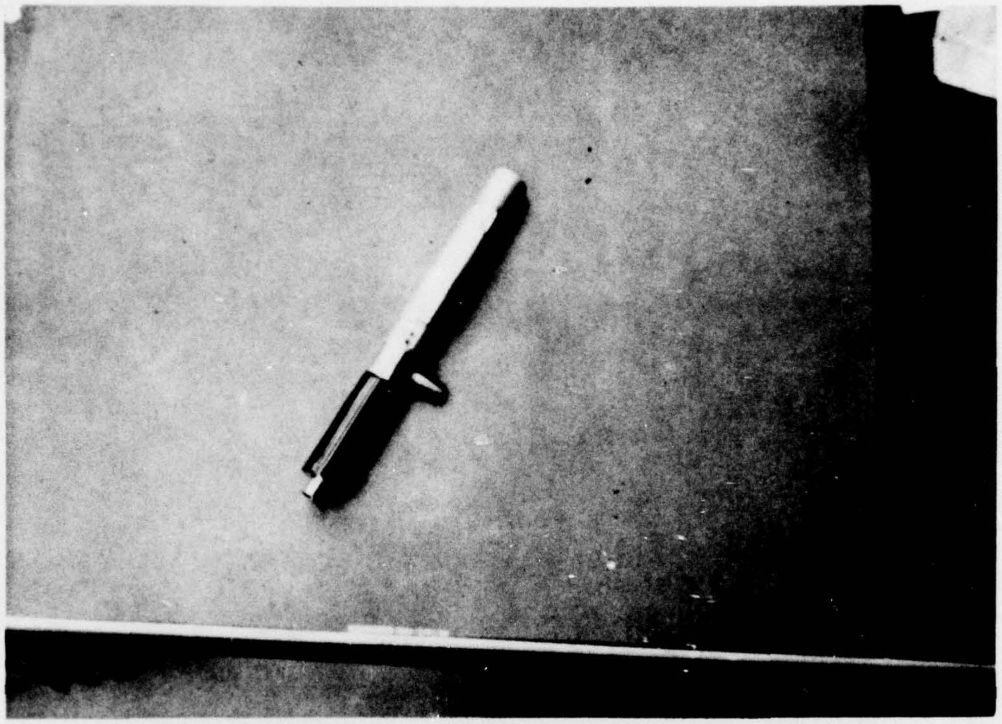
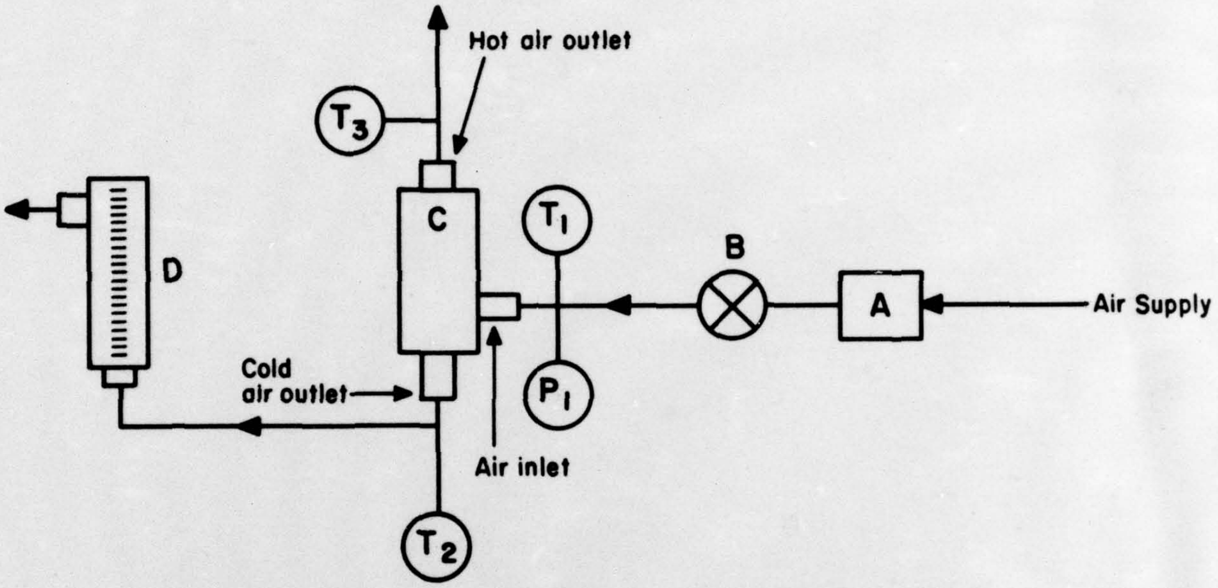


Figure 1. The Vortex Tube Cooler.



LEGEND:

A	Mass Flowmeter
B	Pressure Regulating Valve
C	Vortex Tube
D	Flowmeter
T_1	Vortex Tube Inlet Temperature
P_1	Vortex Tube Inlet Pressure
T_2	Vortex Tube Cold Outlet Temperature
T_3	Vortex Tube Hot Outlet Temperature

FIGURE 2. TEST SET-UP

APPENDIX B. REFERENCES

1. Ruch, Theodore C., and Patton, Harry D., Physiology and Biophysics, nineteenth edition, W. B. Saunders Company, 1966.

2. Marks, Lionel S., Mechanical Engineers Handbook, sixth edition, McGraw-Hill Company, 1958.

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