CHAPTER 10

SINGLE DRUM WINCH DESIGN

Michael Markey

PREFACE

Third Addition - Chapter 10

In the eleven years since the second edition appeared the single-drum of "load-drum" winch has seen notable evolution. The natural opposite to a "load-drum" is a "storage drum" as with Traction Winch systems. Storage "reels" do not qualify as winches, and will not be covered here.

A "new" rating definition has become more widely used. "Deck Lift" calls out the maximum "air-weight" which a winch can deploy. The number has been available on layer-by-layer drum charts, but it is being recognized as another important defining parameter.

Two interpretations of "deck-lift" require clarification. The more obvious is the winch drum's available output line pull at the full layer. This is where loads are handled at the deck and through the surface plane. Many drum proportions result in a lesser payload capacity being available with some amount of wire paid out. "Live Load" (sum of payload + drag) deducts the wire weight from drum pull. This non-linear value can reach a "minimum which is substantially less than the full-drum pull. If a payload is to be lowered below the depth where this "minimum" occurs, the winch will theoretically be unable to recover it -- baring drive overload availability. The conservative definition of "deck-lift" would use this minimum "live-load" value based on full depth deployment. However, since builders prefer to present their machines in the best light, the full-drum value seems likely to prevail.

AC-Variable Frequency winch drives have come of age, demonstrating enough reliability to become the cost-effective electric option over SCR-DC. Availability of modular planetary gear reducers has enlarged the layout window for the winch designer.

Hydraulic winches have kept pace, with the wider range of hydraulic components and the increased flexibility of hydraulic controls - with or without electronic and digital presence. Increased availability of large displacement hydraulic motors has changed the look of many winches. A small lower-cost motor plus a planetary unit makes an interesting option to a direct large motor, and can also simplify or eliminate conventional gear trains.

Off-the-shelf Programmable Logic Controllers (PLC) and higher-level digital drives in combination with precision spooling have provided the ability to offer "layer-compensated" output. This gives the same pull and speed at each layer of wire -- thus matching two of the features which have so far justified the cost, complexity and wire bends of the traction type machines.

Fiber-optic cables and multi-function umbilical cables have demanded large diameter drum cores and sheave suites, along with the provision of more elaborate slip-ring packages. Fiber optic cables are gaining in their ability to be stored at higher working tensions, and thereby reducing the low-tension storage advantage of the traction type winch systems.

A new method of spooling certain types of softer or less-circular tension members is worth consideration. Experience with the high performance soft lines used aboard the growing class of escort and ship-assist tugs has proved that the "open-lay" or "universal spooling" concept can greatly reduce line "pull-down" problems. These large braided lines are soft when slack, oval shaped around bends, and very slippery. It remains to be seen whether a fast fairlead traverse rate with wide gaps between turns and many cross-overs between layers will be a benefit with particular oceanographic tension members which have so far proved hard to spool cleanly.

A number of winches sized to carry 5000 and 6000 meters of wire have provided "enough" reach, while being smaller, lighter and less costly than the older standard of 10,000 meters. The practice of carrying around "one's spare wire" has become merely an option, in the face of limited space and economic constraints.

A semi-production class of portable winch systems with perhaps a maximum capacity of 3000 meters of 0.322" CTD cable (or its inevitable replacement...) could be a useful tool aboard the large and mid-size ships. One logical approach for this service would be a modularized electro-hydraulic suite with a single

460/3/60 "fleet-standard" electrical cable plug and receptacle configuration. In the interest of package location and maintenance access, it may be desirable to have the hydraulic power pack as a separate module which could be attached to the winch, or remote. An important feature would be drum interchangeability. If shorter cable lengths were to be used, spare drums with larger barrel diameters could be provided. Storage space for hoses and power cables, proper lifting eyes and fork-lift sockets, and perhaps frameworks to accept "shipping plywood" panels would add value to such systems.

Smaller yet are the 1000 and 2000 meter machines for the new class of inshore and near-shore boats. (see Photos # 6 & 7) As demands for environmental data proliferate, more jurisdictions and enterprises which include a beach will need scientific data of the same quality and quantity as the blue-water boats provide. Weight limits aboard 30 ft to 80 foot boats are leading to aluminum construction, and with the potential numbers of this type vessel, short-delivery semi-stock winch families are being developed. Often these near-shore boats see shorter and steeper waves than do the big ships. These conditions exacerbate the ship-motion and slack-wire problems, and require maximum winch controllability, along with careful cable-lead arrangements.

One frequently-requested feature has remained illusive. "Why not a "dithering" winch drum for motion-compensation?" After costly failed attempts, the fundamentals of rotational inertia appear to remain stubbornly in place. Instead, separate hardware such as the "nodding boom" and the "ram tensioner" appear to be the better way to help a winch move a payload at a constant rate relative to the earth as the ship's overboard sheave dances in the bight of the wire.

Electronics have taken over the "cable-data" sub-systems. The mechanical tachometer and the wheel counter have taken their rightful places in the museums. (Except possibly for the smallest and most basic machines...) Line speed and count signals are provided by proximity sensors or optical encoders. Line tension signals from moving lines originate with strain-gages on sheave axle pins. Often these signals originate from sheaves which "ride" the traversing fairlead heads. It is important to provide a conductor-protecting slack-loop", such as teflon-lined stainless armored hydraulic hose between the head and a fixed J-box on the winch.

The wire data is available on PC screens or dedicated PLC windows, as well as analog meters, and the numbers are readily routed to the vessel's own computers, and then onward to anywhere on or off the planet. Analog meters retain their natural advantage of providing an "instant visual impression" which is frequently useful to a busy operator. (See photo # 11)

The possibility of programming a complete winch time-motion "sequence" remains available, but this feature has seldom been used. Not everything which is possible is worth doing.

Chapter 10 Single-Drum or "Load-Drum" Research Winches

1.0 BASICS OF OPERATION

The single-drum research winch has been the data-gathering mainstay of sea-going wire handling and storage since the activity passed the hand-line and bucket stage.

When discussing these machines, the oceanographic community applies an interesting mix of English and Metric units. Wire diameters have been usually expressed in inches, although millimeters are creeping in. The length of wire payed out is commercially and scientifically voiced in meters, while the Navy generally calls out feet. Line pulls are most often in pounds, but kilograms and kiloNewtons are here.

Speeds are referred to in meters per minute, but many of us still design in feet per minute. Horsepower remains the term of capability, but kilowatts loom.

To convert kilowatts into horsepower, multiply kw by 1.341

To convert meters to feet, multiply meters by 3.2808

To convert millimeters to inches, multiply mm by 0.0394
(25.38 mm = 1 inch)
To convert kilograms to pounds, multiply kg by 2.205
To convert kiloNewtons to pounds, multiply kN by 224.82
(4.448 kiloNewtons equals 1000 pounds)

Winch builders do their best to speak in the terminology which the customer brings to the table.

Operators are beginning to call out the air-weight "DECK-LIFT" which a winch will handle -- most logically at the outer layer of the available wire. This "spec. item" is useful in that it can help shape drum proportions, and clearly tells the operator one very important performance boundary value.

Research winches handle wire, cable and umbilical sizes from 1/8" on up, with a wide application plateau at 0.680" and 0.681", and with no real end in sight.

Lengths of wire vary from a few hundred feet to as much as 43,000 feet. Empty winch weights range from 300 lb. to 80,000 lb. (the side-by-side two drum unit aboard the icebreaker "Nathaniel Palmer".)

The term "Single Drum Winch" can be a misnomer, since two or three "Load Drums" can be combined on a single structure, in side-by-side or in "waterfall" arrangement. When each drum has its own independent drive the terms "dual winch" or "triple winch" are appropriate. The alternative is to employ a single drive and clutch-in the one desired drum.

These and other variations maintain the largely custom nature of this equipment. Efforts have been made to "standardize" a family of machines -- often the effort comes from a regulatory or government body. Each manufacture's ingenuity, design approach and market focus has continued to confound the "standardizers. Having said that, each builder has a core of his own "good practice" which will be repeated as much as possible to help control engineering cost.

With smaller winches, a "quantity-built" design becomes feasible, although often "custom" variations will be required and the winch returns to custom or semi-custom status.

A primary advantage of a "Load Drum" winch is the directness of the cable's path, when compared to a traction machine. At the winch, the cable bends itself continuously in the same direction with small radius changes as the drum fills or empties. Overboard sheaving is common to both types of winch.

With proper selection of sheave and drum barrel diameters, and the general application of the "Lebus" grooved shell, Load-Drum spooling is a relatively gentle process on the wire, and results in good wire life. Photographs # 8,9 & 10 show spooling the way it is intended to be. While factory or dockside drum loadings are "artificial" environments with controlled hold-back tension, the designer's true delight arrives when the at-sea deployments behave in the same precision way.

It is worth noting that "Lebus" suggests that its shells are at their best up to approximately 16 layers. Few winch designs allow the width implied by such a shallow drum, and in fact the "Lebus" offsets remain visible and effective through many more layers. The forced "Lebus" crossovers will often migrate from their initial 180 degree locations, while continuing to exert wire control.

2.0 WINCH DRUMS -- DESIGN CHARTS CAPACITIES -- PROPORTIONS

A fundamental characteristic of the "Load Drum" Winch is the change of working radius which occurs as the drum fills and empties. Available line pull is the greatest at the barrel layer, whereas the greatest speed is available at the full drum. The spreadsheets which illustrates this radius-dependent output are the subject of this section.

2.1 Drum Charts

Many forms of spreadsheet can be written to show each layer's geometry and the pulls and speeds available, once the winch's design parameters have been selected. Pages 5, 6, 7, & 8 illustrate data for winches with three electric drives and one hydraulic drive. Page 5 shows a small 7-1/2 hp, AC-VF, semi-production winch. Page 6 shows a 50 hp SCR/DC machine with a single gear ratio. Page 7 shows a 75 hp SCR/DC unit with gear shift between two gear ratios, and page 8 shows a 100 hp, gear-shift AC/hydraulic machine.

DRUM CAPACITY AND PERFORMANCE CHART

MARKEY RESEARCH WINCH DRUM & PERFORMANCE CHART
MMCo. Type = COM-07-X2CL Done For
MMCo. SERIAL @ 17708

Cable Dia	0.322	Fce Width	21.000
Flang Dia	26.750		
Barel Dia	12.190		
Flng Dpth	7.280		
Act Layers	22.609		
USE LAYERS	21.000		

DATE 02-01-2000
DRIVE TYPE = AC Variable Frequency 7-1/2 HP, A.C. V-F

Wt.in H20	0.144 lb.	Fast rpm	2,520
Ult.Stngth	10,000 lb. free end	Slow rpm	1,800 Base
Deploy	6,562 feet	RPMratio	1.400
Barel Pull	3,950 lb.	BaseFreq	60 Hertz
Line Speed	52 ft/min (@ barrel)	Max Freq	84 Hertz

								BASE MOTOR RATING 60 Hz				FREQUENCY ENHANCED 84 Hz					
	Layer Number	Pitch Diam.	Feet/ Wrap	Feet/ Layer	Feet ON	Feet OFF	H20 Wt. of Wire	PULL	Live Load	Ft/ Min	Meters/ Min	PULL	Live Load	Ft/ Min	Meters\ Min	Layer Number	
	24	27.324	7.153	454	7,947	-931	-134	1,975	2,109	113	34.4	1,339	1,473	158	48.2	24	
	23	26.680	6.985	444	7,493	-487	-70	2,022	2,092	110	33.6	1,371	1,442	154	47.0	23	
	22	26.036	6.816	433	7,049	-54	-8	2,072	2,080	108	32.8	1,405	1,413	151	45.9	22	
	21	25.392	6.648	422	6,616	363	53	2,125	2,072	105	32.0	1,441	1,388	147	44.8	21	
	20	24.748	6.479	411	6,194	779	112	2,180	2,068	102	31.2	1,479	1,366	143	43.6	20	
	19	24.104	6.310	401	5,783	1,180	170	2,238	2,068	100	30.4	1,518	1,348	139	42.5	19	
	18	23.460	6.142	390	5,382	1,570	226	2,300	2,074	97	29.5	1,560	1,334	136	41.4	18	
	17	22.816	5.973	379	4,992	1,949	281	2,365	2,084	94	28.7	1,604	1,323	132	40.2	17	
	16	22.172	5.805	369	4,613	2,318	334	2,433	2,100	92	27.9	1,650	1,317	128	39.1	16	
	15	21.528	5.636	358	4,244	2,676	385	2,506	2,121	89	27.1	1,700	1,314	125	38.0	15	
	14	20.884	5.467	347	3,886	3,023	435	2,583	2,148	86	26.3	1,752	1,317	121	36.8	14	
MID	13	20.240	5.299	336	3,539	3,359	484	2,666	2,182	84	25.5	1,808	1,324	117	35.7	13	MID
	12	19.596	5.130	326	3,203	3,685	531	2,753	2,223	81	24.7	1,867	1,337	113	34.6	12	
	11	18.952	4.962	315	2,877	4,000	576	2,847	2,271	78	23.9	1,931	1,355	110	33.4	11	
	10	18.308	4.793	304	2,562	4,305	620	2,947	2,327	76	23.1	1,999	1,379	106	32.3	10	
	9	17.664	4.624	294	2,257	4,598	662	3,054	2,392	73	22.2	2,071	1,409	102	31.1	9	
	8	17.020	4.456	283	1,964	4,881	703	3,170	2,467	70	21.4	2,150	1,447	98	30.0	8	
	7	16.376	4.287	272	1,681	5,153	742	3,295	2,552	68	20.6	2,234	1,492	95	28.9	7	
	6	15.732	4.119	262	1,409	5,415	780	3,429	2,650	65	19.8	2,326	1,546	91	27.7	6	
	5	15.088	3.950	251	1,147	5,666	816	3,576	2,760	62	19.0	2,425	1,609	87	26.6	5	
	4	14.444	3.781	240	896	5,906	850	3,735	2,885	60	18.2	2,533	1,683	84	25.5	4	
	3	13.800	3.613	229	656	6,135	883	3,910	3,026	57	17.4	2,651	1,768	80	24.3	3	
	2	13.156	3.444	219	427	6,354	915	4,101	3,186	54	16.6	2,781	1,866	76	23.2	2	
	1	12.512	3.276	208	208	6,562	945	4,312	3,367	52	15.8	2,924	1,979	72	22.1	1	

KJM disc #185
A:17708.cht

PERFORMANCE CHART

MARKEY RESEARCH WINCH DRUM & PERFORMANCE CHART DATE= JUL-17-97
MMCo. Type DESH-5 Done For DRIVE TYPE DC Elect 50 hp

Cable Dia	0.322	Fce Width	28.000	Wt.in H2O	0.139 lb.	Fast rpm	1,800
Flang Dia	40.000			Ult.Stngth	11,000 lb.	Slow rpm	1,200
Barel Dia	18.000			Deploy	19,674 feet	RPMratio	1.500
Flng Dpth	11.000			Barel Pull	12,000 lb.	Sftratio	3.070
Act Layers	34.161						
USE LAYERS	36.000						

Layer Number	Pitch Diam.	Feet/ Wrap	Feet/ Layer	Feet ON	Feet OFF	H2O Wt. of Wire	PULL	Live Load	Ft/ Min	Meters/ Min	PULL	Live Load	Ft/ Min
34	39.574	10.360	891	22,160	-1,595	-222	5,556	5,777	220	67.2	3,704	3,926	330
MAX 33	38.930	10.192	877	21,269	-718	-100	5,648	5,748	217	66.1	3,765	3,865	325
DESIGN 32	38.286	10.023	862	20,392	144	20	5,743	5,723	213	65.0	3,828	3,808	320
	37.642	9.855	848	19,530	991	138	5,841	5,703	210	63.9	3,894	3,756	314
30	36.998	9.686	833	18,683	1,824	254	5,943	5,689	206	62.8	3,962	3,708	309
29	36.354	9.517	819	17,850	2,643	367	6,048	5,681	202	61.7	4,032	3,665	304
28	35.710	9.349	804	17,031	3,447	479	6,157	5,678	199	60.6	4,105	3,626	298
27	35.066	9.180	790	16,227	4,236	589	6,270	5,681	195	59.5	4,180	3,591	293
26	34.422	9.012	775	15,438	5,011	697	6,387	5,691	192	58.4	4,258	3,562	287
25	33.778	8.843	761	14,663	5,772	802	6,509	5,707	188	57.3	4,339	3,537	282
24	33.134	8.674	746	13,902	6,518	906	6,636	5,730	184	56.2	4,424	3,518	277
23	32.490	8.506	732	13,156	7,249	1,008	6,767	5,759	181	55.1	4,511	3,504	271
22	31.846	8.337	717	12,425	7,966	1,107	6,904	5,797	177	54.0	4,603	3,495	266
21	31.202	8.169	703	11,708	8,669	1,205	7,046	5,842	174	52.9	4,698	3,493	261
MID 20	30.558	8.000	688	11,005	9,357	1,301	7,195	5,894	170	51.9	4,797	3,496	255
SCOPE 19	29.914	7.831	674	10,317	10,030	1,394	7,350	5,956	167	50.8	4,900	3,506	250
18	29.270	7.663	659	9,644	10,689	1,486	7,512	6,026	163	49.7	5,008	3,522	244
17	28.626	7.494	645	8,985	11,334	1,575	7,681	6,105	159	48.6	5,120	3,545	239
16	27.982	7.326	630	8,340	11,964	1,663	7,857	6,194	156	47.5	5,238	3,575	234
15	27.338	7.157	616	7,710	12,579	1,749	8,042	6,294	152	46.4	5,362	3,613	228
14	26.694	6.988	601	7,095	13,180	1,832	8,2[illegible]	6,404	149	[illegible]5.3	5,491	3,659	223
13	26.050	6.820	587	6,494	13,767	1,914	8,440	6,526	145	44.2	5,627	3,713	218
12	25.406	6.651	572	5,907	14,339	1,993	8,654	6,661	141	43.1	5,769	3,776	212
11	24.762	6.483	558	5,335	14,896	2,071	8,879	6,808	138	42.0	5,919	3,849	207
10	24.118	6.314	543	4,778	15,439	2,146	9,116	6,970	134	40.9	6,077	3,931	201
9	23.474	6.145	529	4,235	15,968	2,220	9,366	7,147	131	39.8	6,244	4,025	196
8	22.830	5.977	514	3,706	16,482	2,291	9,630	7,340	127	38.7	6,420	4,129	191
7	22.186	5.808	500	3,192	16,981	2,360	9,910	7,550	124	37.6	6,607	4,246	185
6	21.542	5.640	485	2,693	17,466	2,428	10,206	7,778	120	36.6	6,804	4,376	180
5	20.898	5.471	471	2,208	17,937	2,493	10,521	8,028	116	35.5	7,014	4,521	175
4	20.254	5.302	456	1,737	18,393	2,557	10,855	8,299	113	34.4	7,237	4,680	169
3	19.610	5.134	442	1,281	18,834	2,618	11,212	8,594	109	33.3	7,475	4,857	164
2	18.966	4.965	427	840	19,261	2,677	11,593	8,915	106	32.2	7,728	5,051	158
1	18.322	4.797	413	413	19,674	2,735	12,000	9,265	102	31.1	8,000	5,265	153

Base Motor Rating__________ Field-Weakened Ratin

SEARCH WINCH DRUM & PERFORMANCE CHART
DESH-5 S/N 16665 Done For

DATE= December 15, 1995
DRIVE TYPE 75HP AC/SCR DC Electric

timate

meters

Barrell Diameter

iameter

1.109	3.485	402	11,298	MAXIMUM CAPACITY
1.093	3.433	397	10,896	
1.076	3.382	391	10,499	DESIGNED CAPACITY
1.060	3.330	385	10,109	
1.044	3.279	379	9,724	
1.027	3.228	373	9,345	
1.011	3.176	367	8,973	
0.995	3.125	361	8,606	
0.978	3.074	355	8,245	
0.962	3.022	349	7,890	
0.946	2.971	343	7,541	
0.929	2.919	337	7,198	
0.913	2.868	331	6,860	
0.897	2.817	325	6,529	
0.880	2.765	319	6,204	
0.864	2.714	313	5,884	
0.847	2.662	308	5,571	
0.831	2.611	302	5,264	MID-SCOPE
0.815	2.560	296	4,962	
0.798	2.508	290	4,666	
0.782	2.457	284	4,377	
0.766	2.405	278	4,093	
0.749	2.354	272	3,815	
0.733	2.303	266	3,543	
0.717	2.251	260	3,277	
0.700	2.200	254	3,017	
0.684	2.149	248	2,763	
0.668	2.097	242	2,515	
0.651	2.046	236	2,273	
0.635	1.994	230	2,036	
0.618	1.943	224	1,806	
0.602	1.892	218	1,582	
0.586	1.840	213	1,363	
0.569	1.789	207	1,151	
0.553	1.737	201	944	
0.537	1.686	195	743	
0.520	1.635	189	549	
0.504	1.583	183	360	
0.488	1.532	177	177	

Pitch
Diam.
(METERS)

Motor

PLT

GH SPEED GEAR

MARKEY RESEARCH WINCH DRUM & PERFORMANCE CHART DATE= 10/11/97
MMCo. Type DUSN-5 Done For DRIVE TYPE = Hydraulic

Cable Dia	0.322	Fce Width	38.000	Wt.in H20	0.144 lb.
Flang Dia	44.000			Ult.Stngth	10,000 lb.
Barel Dia	18.750			Deploy	32,808 feet
Flng Dpth	12.625	Air Gap	0.487	Barel Pull	11,000 lb.
Act Layers	39.208	Gap X /100	0.013	Line Speed	165 ft/min (@ barrel)

Sftratio 1.318

Layer Number	Pitch Diam.	Meter/ Wrap	Meter/ Layer	Meters ON	Meters OFF	H20 Wt. of Wire	PULL	Live Load	Ft/ Min	Meters/ Min	PULL	Live Load	Ft/ Min
40	44.188	3.526	411	11,762	-1,351	-195	4,748	4,942	382	116.5	3,602	3,797	504
39	43.544	3.475	405	11,351	-946	-136	4,818	4,954	377	114.8	3,655	3,792	497
38	42.900	3.423	399	10,946	-547	-79	4,890	4,969	371	113.1	3,710	3,789	489
37	42.256	3.372	393	10,547	-155	-22	4,965	4,987	366	111.4	3,767	3,789	482
36	41.612	3.320	387	10,154	232	33	5,042	5,008	360	109.7	3,825	3,792	474
35	40.968	3.269	381	9,768	613	88	5,121	5,033	354	108.0	3,885	3,797	467
34	40.324	3.218	375	9,387	988	142	5,203	5,060	349	106.3	3,947	3,805	460
33	39.680	3.166	369	9,012	1,357	195	5,287	5,092	343	104.6	4,011	3,816	452
32	39.036	3.115	363	8,643	1,720	248	5,374	5,127	338	102.9	4,078	3,830	445
31	38.392	3.064	357	8,280	2,077	299	5,464	5,165	332	101.2	4,146	3,847	438
30	37.748	3.012	351	7,923	2,428	350	5,558	5,208	327	99.5	4,217	3,867	430
29	37.104	2.961	345	7,572	2,772	399	5,654	5,255	321	97.8	4,290	3,891	423
28	36.460	2.909	339	7,227	3,111	448	5,754	5,306	315	96.1	4,366	3,918	416
27	35.816	2.858	333	6,888	3,444	496	5,857	5,362	310	94.4	4,444	3,948	408
26	35.172	2.807	327	6,555	3,771	543	5,965	5,422	304	92.7	4,526	3,983	401
25	34.528	2.755	321	6,229	4,092	589	6,076	5,487	299	91.0	4,610	4,021	394
24	33.884	2.704	315	5,908	4,407	635	6,191	5,557	293	89.4	4,698	4,063	386
23	33.240	2.652	309	5,593	4,716	679	6,311	5,632	288	87.7	4,789	4,109	379
MID 22	32.596	2.601	303	5,284	5,019	723	6,436	5,713	282	86.0	4,883	4,160	372
21	31.952	2.550	297	4,981	5,316	766	6,566	5,800	276	84.3	4,982	4,216	364
20	31.308	2.498	291	4,683	5,607	807	6,701	5,893	271	82.6	5,084	4,277	357
19	30.664	2.447	285	4,392	5,893	849	6,842	5,993	265	80.9	5,191	4,342	350
18	30.020	2.395	279	4,107	6,172	889	6,988	6,170	260	79.2	5,302	4,414	342
17	29.376	2.344	273	3,828	6,445	928	7,142	6,214	254	77.5	5,419	4,490	335
16	28.732	2.293	267	3,555	6,712	966	7,302	6,335	249	75.8	5,540	4,573	328
15	28.088	2.241	261	3,288	6,973	1,004	7,469	6,465	243	74.1	5,667	4,663	320
14	27.444	2.190	255	3,027	7,228	1,041	7,644	6,604	237	72.4	5,800	4,759	313
13	26.800	2.139	249	2,772	7,477	1,077	7,828	6,751	232	70.7	5,939	4,863	306
12	26.156	2.087	243	2,523	7,720	1,112	8,021	6,909	226	69.0	6,086	4,974	298
11	25.512	2.036	237	2,280	7,957	1,146	8,223	7,077	221	67.3	6,239	5,093	291
10	24.868	1.984	231	2,042	8,189	1,179	8,436	7,257	215	65.6	6,401	5,222	284
9	24.224	1.933	225	1,811	8,414	1,212	8,661	7,449	210	63.9	6,571	5,359	276
8	23.580	1.882	219	1,586	8,633	1,243	8,897	7,654	204	62.2	6,750	5,507	269
7	22.936	1.830	213	1,367	8,846	1,274	9,147	7,873	198	60.5	6,940	5,666	262
6	22.292	1.779	207	1,154	9,054	1,304	9,411	8,107	193	58.8	7,140	5,837	254
5	21.648	1.727	201	946	9,255	1,333	9,691	8,358	187	57.1	7,353	6,020	247
4	21.004	1.676	195	745	9,450	1,361	9,988	8,627	182	55.4	7,578	6,217	239
3	20.360	1.625	189	550	9,639	1,388	10,304	8,916	176	53.7	7,818	6,430	232
2	19.716	1.573	183	361	9,823	1,414	10,641	9,226	171	52.0	8,073	6,659	225
1	19.072	1.522	177	177	10,000	1,440	11,000	9,560	165	50.3	8,346	6,906	217

<- HIGH PULL / LOW SPEED -> <- LOW PULL / HIGH SP

At MMCo. we choose to locate the barrel layer (#1) at the bottom of the chart, and work upwards, since this gives a visual analog to what one sees when looking at an actual drum as it is filling.

The normal "Load Winch" is based on having single-value drum torques and drum revs/min available across all layers, at each "point" on the drive's performance envelope.

The conservative approach to a Drum Chart is to assume that the wires stack vertically atop each other. It is clear that "cannon-ball" stacking does take place, with each wire laying in the valley between its two lower supporters. However, at the layer "cross-over" points, the wires ARE radially aligned. When a Lebus shell is used, two cross-overs occur at 180 degrees apart on each turn. Thus vertical stacking makes sense for the spreadsheet, and gives conservative drum volumes, with flange margin. The left portion of a typical chart defines the geometry and the summations of wire footage and weight as the drum fills. "Inverse" data columns show footage and wire-weight payed out. It should be noted that these two columns depend upon filling the drum to its rated capacity. If a drum is loaded only half way, all the chart rating data changes since less wire weight applies at each layer. New charts can be quickly prepared for partial drum loads.

The important portions of each chart are the data columns shown at the "right." The format will vary depending upon the number of gear ratios available, as well as how many motor speed/pull ratings are defined for the winch drive.

For each "rating point" on the performance map, the drum output pull and speed are linear with radius change. We show the line speeds in both feet/min and in meters/min. The more interesting data column at each rating point is that known as "LIVE LOAD."

<u>"Live Load"</u>

Live Load is the simple subtraction of the accumulated wire weight from the available drum line pull at each layer. Considering the wire's weight as parasitic leaves a non-linear summation of forces which is much more useful to the winch operator than the basic drum pull value.

Live Load is also definable as the sum of the payload's in-water weight, it's drag, and the drag of the cable. Small acceleration loads are usually negligible.

Drag values can be estimated as non-linear functions of the payload's speed through the water, as can the cable's drag under a variety of conditions. In practice, this level of "science" is usually overkill, and in any case not accurately available until the winch is designed, built and deployed with real payloads. The Live Load sum is an early design value, and gives the operator an adequate guide.

Scanning a Live Load data column will show that the values usually trend through a shallow "minimum." Where that occurs depends upon the drum proportions. Taken literally, the lowest value of Live Load is the greatest "weight + drag" which can be payed out to full wire depth and successfully recovered. With a marginal winch drive or a unusually high load, hoisting speed can usually be reduced to shift available energy over from "drag" to "weight coming up."

Electric systems mask the importance of the minimum Live Load by providing built-in overload capability. Simple hydraulic systems reach their relief valve pressure settings and just stall. The elaborate hydraulic circuits are more flexible, as will be discussed later.

With multi-ratio gearing and multi-speed drives, the "Live Load" data will change from rating point to rating point out of all proportion to the drive rating differences. The wire weight remains the same, and seeking higher line speeds can reduce Live Load so much that the faster operating points become useful only for high-speed payout.

2.2 Drum Proportions

2.2.1 Drum "Barrel" or "Core" Selection

A prospective winch owner should be prepared to define the primary wire by diameter and length. Projecting future applications over a thirty-plus year winch life is an awkward but necessary exercise, and often leads to the provision of "easily" interchangeable drums and quick-change fairlead drive components. The initial projected wire parameters will define the drum and the rest of the winch.

The diameter ratio between the drum barrel and the wire (D/d) is critical. The wire or cable builders normally provide a minimum D/d as part of their specification, and this value can be used to size the barrel -- hoping that the winch will never need to handle a "stiffer" or larger product.

At least four reality factors suggest that the winch should provide a somewhat larger barrel than the initial wire's minimum.

a) Loads become larger over the years.
b) New payloads are appearing rapidly, with requirements for differing wires, EM cables or Fiber Optic cables.
c) Wire life is improved when it is spooled at a larger radius than that which the wire builder considers minimum.
d) A larger barrel results in fewer wire layers. Spooling benefits from keeping the number of layers as small as practical.

Three contravening factors mitigate against selection of a larger-than-minimum drum. These are space, weight and cost !

D/d ratios vary enormously for different winch applications. Escort tugs can wrap 4" diameter braided "Spectra" or "Plasma" type soft ropes onto a 30" dia. barrel, for a 7-1/2 to 1 D/d. Steel towing wires should see 15 to 1, but are often fudged down to 13 to 1 with the assumption that the barrel layer is seldom used.

The UNOLS "standard" 0.322" CTD cable shows a 12" minimum diameter, or 37 to 1. One 0.680" EM cable shows a 28" minimum diameter, for 41 to 1. A typical 0.681" fiber-optic cable shows a 48" minimum diameter, for 70 to 1. This illustrates the need to know or assume the intended tension member at the start of the design process.

2.2.2 Drum Width and Flange Dimensions

With the barrel diameter established, the designer will balance face width against flange diameter, based upon experience and what "looks right." Occasionally available space will dictate a long and shallow drum. This requires a stiffer drum structure and fairlead assembly to avoid deflections. At the opposite extreme, MMCo. has provided wire rope anchor windlasses where a tall and narrow drum was demanded by the overboarding layout and where a fairleader was not practical.

Excessive drum depth increases the flange steel's tendency to creep into a permanently deformed "hour-glass" or cone shape. If the face width at the outside is greater than that at the barrel, spooling suffers. Contrary to common sense, the small research wires require stiffer drum flanges than do those for large towing wires which see much higher pull ratings. Good practice calls for heavy duty flanges, with clean-up cuts on the inside to maintain square and parallel drum ends.

If a sample were taken of many research winches built by the many good builders, we suspect that there would be a rather narrow grouping of empirical values which constitute rational drum proportions.

Flange margin should be provided, beyond what the design Drum Chart shows as the outer layer's diameter. Spooling can become irregular for various reasons, with wire piling up at one end -- not desirable, but it happens. A better reason is to allow for future installation of a larger wire. For 0.322" cable, if the design drum chart shows a 41" o.d. for the outer layer, it would be reasonable to call out a 44" diameter flange.

3.0 "LEBUS" GROOVED SHELLS

The Lebus shell is essentially a grooved cylinder, manufactured from either steel, aluminum or fiberglass, that is designed to assure the proper seating of a specific rope or cable and the proper movement and spacing of that wire between the flanges of the winch drum. In order to effectively use the Lebus shells the winch drum must have flanges that are perpendicular to the barrel or core of the smooth winch drum. The shells, when delivered are split for easy installation on the winch or take-up spool and attachment can be accomplished by either welding or bolting the shell in place. Where winch systems utilize more than one size of wire or cable during their operational life, it is recommended that the bolt-on technique be used. Except in special situations, most research winches NEED this shell. If spare interchangeable drums are provided, each may require its own shell.

The unique twin half-wire-width crossover feature positively locates the barrel layer of wire, and allows the inter-wrap air gap to be much closer than does a smooth barrel. A "Lebus-spooled" air gap can be in the order of 1-1/2 to 2% of the "load-settled" slack wire diameter. If a deck engineer must "hammer" the first layer onto a bare drum with a stick and a maul, a design air gap of 6% to 9% is necessary. This reduces drum capacity and unsettles the fairleading.

Good practice requires that a sample of the ACTUAL cable be sent to the "Lebus" firm for incremental diameter checks at varying loads, both increasing and decreasing. For small wires a 30 foot sample works well. Given a tabulation of the diameter versus load, and the degree to which the sample's final diameter remains below its design nominal size, the winch designer can determine how may wraps should be spooled onto each layer.

For reasons which "Lebus" can explain, the winch builder should allow face width for a number of wraps which is an INTEGER PLUS ONE HALF. When calculating his fairlead drive, he must recognize that the number of drum turns is 1/2 fewer than the number of Lebus grooves. e.g., 100-1/2 grooves give 100 turns. The section covering fairleaders will expand on the implications.

4.0 WINCH PERFORMANCE

Line Pull Ratings versus Wire Strength

Given the likelihood that a research winch will need to handle increasing payloads over its decades of service, and the equal likelihood that a now-standard cable, e.g. the UNOLS pool 0.322" EM cable, will eventually give way to a more capable tension member, the question of "how much pull" is not simple. At one boundary, a ship's available winch drive power may force the balancing of pull versus speed -- recognizing that there must be enough line pull to get the work done, or "don't bother." Speed is the secondary parameter.

With adequate power available, the breaking strength of the present and potential future wires enters the picture. One arbitrary approach would be to design the winch drive and scantlings to break the basic wire at the barrel layer. The drum geometry and its Chart will show whether sufficient "Deck Lift" is available with the drum filled. Often a winch will be given the increased ability to break the wire "up the stack" in order to increase the pulls available higher up, (less wire out) where most of the work may be done.

Dipping, towing and core pull-out all effect the thought process, as does the possibility of a load or wire becoming snagged. It is clearly impractical to carry wire that an R/V's propulsion can't break, (as opposed to a tug..,) and it is equally necessary that the winch and the entire rigging system be tough enough to break any intended wire without mechanical damage.

RATED LINE PULL is best determined by close consideration of the projected payloads, experience, and the operator's instinct, as passed through the hands of the system specifier.

Multi-range winches will often be run most of their lives in the higher-speed-and-reduced-pull-range, with the "cable-parting" grunt-range reserved for special situations.

4.2 Line Speed

Hoisting speeds are often a case of "more is better." Assuming proper speed control to allow gentle handling of sampling nets, etc., minimizing time on station calls for all the hoisting speed the ship's power supply will allow, without increasing the drag forces beyond reason. The multi-range winch package recognizes the fact that most loads are not at the pull-maximum, and provides higher speeds at reduced load, in a variety of ways.

Lowering speed is a function of how fast the payload will fall through the water; a widely variable number. Many operators have set 100 M/min as a nominal maximum. Slack wire is a high-level "No-No", since it allows the wire to hackle or kink. Wire breakage (and another package insurance claim), serious loss of wire strength, or at least a spooling mess results.

From a design standpoint, most winches will payout as fast as they will hoist. It becomes the responsibility of the man on the joystick, with the help of a good tension metering system, to avoid excessive payout speeds. As will be noted later, a computer can take over part of the control task, but SEAMANSHIP cannot be eliminated. The winch driver should be a "top-hand."

5.0 WINCH DRIVES

Steam is a magnificent fluid for powering a winch. With the re-powering of the "Atlantis II" decades ago, and the electrification of its 10"x10" integrated two-cylinder steam trawl winch, that era ended. The present alternatives are electrical drives or hydraulic drives.

5.1 Power Determination

With the pulls and speeds selected, the basic "drum output power" comes from the two well-known relationships:

$$\text{H.P. out} = \frac{\text{Line Pull (lb.) x Line Speed (ft/min)}}{33{,}000}$$

$$\text{H.P. out} = \frac{\text{Output torque (in-lb.) x Output Speed (rev/min)}}{63{,}000}$$

$$\text{H.P. input} = \text{H.P. out x overall winch efficiency}$$

Mechanical efficiencies for machines with spur or planetary reducers and fairleaders will range between 80% and 85%. If worm gearing is involved, an efficiency of 70% to 75% is appropriate. Each manufacturer will have his own design values, ranging from hopeful to conservative.

5.1.1 Electric Power Rating

With a known input power requirement, the electric winch motor can be called out. Conservative practice would always round the nameplate rating UPWARD, to provide reserve, and allow for the fact that all machinery ages. If the nameplate power is close to the calculated need, it may be acceptable to "push" the assumptions and round the electric motor rating DOWNWARD. The "new-standard" squirrel-cage motors used with variable-frequency drives are NEMA-B in design, and provide a 1.0 service factor.

The power rating of an electric winch is usually the nameplate rating on the winch motor itself, without reference to the electrical losses back to the buss.

5.1.2 Hydraulic Power Rating

a) PRESSURE MAKES MOTOR TORQUE, WHICH CREATES LINE PULL

b) VOLUME MAKES MOTOR SPEED, WHICH CREATES LINE SPEED.

Hydraulic drives require the designer and the operator to initially almost ignore "horsepower", and to think in the two separate quantities of "torque" and "speed."
"Horsepower" eventually brings these two back together at the upstream pump drive, but all the intermediate calculations are based on the two separate factors.

A useful preliminary "Rule Of Thumb" says that "1 h.p. into a pump will raise the pressure of 1 g.p.m., by 1,500 psi.

The ratio between "drum power out" and "pump power demand" can be as "good" as 1.6 to 1, or as inefficient as 2.0 to 1. This is a lively issue among hydraulic marketing people. The "Power Rating" of a hydraulic system is usually called out as the rating of the motor or engine used to drive the hydraulic pump.

5.2 Electric Drives

Excepting only the smallest and simplest of applications, the single-speed or even two-speed push-button "START-STOP" drive is not useful. Smooth and predictable variable speed control is an irreducible minimum.

5.2. Direct Current (D.C.)

The older motor-generator type of D.C. drive has followed the steam engine to the museum, as has the constant-voltage "street-car-controller". With "Silicon Controlled Rectifiers" (SCR), the benefits of DC-driven winches can be provided on AC-powered vessels. 100% rated design torque can be maintained down to slow speeds, and by providing higher-than-rated amperage for short times, torque-boost is available. This can provide short time pull increases, such as might be required when pulling a core.

By the process of reducing the motor's field current, higher speeds above "rated" are available, with reduced torque output. An analogy exists between this ability and the "H.P. Limiter" type of hydraulic pump control.

Two important characteristics limit the utility of D.C. drives. Stalled operation is not available since the commutator bars will shortly be destroyed. Carbon-brush wear is a continuing maintenance chore. At voltage-controlled slow speeds, the heat generated will require external blower ventilation.

An occasional winch design will require multiple motors. DC motors have the ability to "lean on the load" together, and divide the work nicely.

5.2.2 Alternating Current (A.C.)

Electronic controls have come of age and provide good reliability. Several levels of "Variable-Frequency" drives are available, with the distinctions better left for the electrical specialist to explain. The terms "Vector" and "Half-Vector" are among those which can mean different things to different drive suppliers. Motors are of the "squirrel-cage" type, although they require specific construction and cooling details to tolerate the artificial "choppy" AC sine-waves which the V.F. drives provide.

The "Variable-Frequency" drive operates by taking in the ship's standard AC power, rectifying it into D.C., and then electronically creating artificial A.C. power at essentially any desired frequency. The squirrel-cage motor responds to the frequency and produces the desired speed.

It is possible to provide 100% rated torque at zero or stall speed, with proper cooling required if the time at stall is "more than a little." The drives are not limited to the source's 60 Hz, but can provide motor frequencies up to 120 Hz. For winch applications, enhanced frequencies of 80 to 90 Hz. will keep the higher motor speeds within reason. Above the "base frequency -- usually 60 Hz), the torque available falls off as frequency and motor speed increase.

At full load or in overload conditions, the torque at enhanced frequency will be below the theoretical "HP=k" curve of torque vs. speed, by the ratio of the "square of the frequencies." As a worst-case example, a heavily-loaded motor with a 60 Hz base (knee) rating will provide only 25% of base-rated torque when operating at 120 hz., as opposed to the theoretical 50% or the more probable 40% to 45% available at light loading.

Paying out a load is always more demanding than hoisting, in that the descending payload is generating energy which must be absorbed in order to maintain speed control. On a ship with ample AC power capacity a "regenerative" winch drive can pass the retarding energy upstream into the buss system. The alternative is termed "dynamic braking" and requires resistor "banks" with proper cooling to dissipate the incoming energy. For long casts the grids must rate for 100% of the "power." This system is a better choice for marginally powered ships, or for self-contained winch packages which must operate on ships-of-opportunity. The winch builder and his electrical people can best aid a winch customer by assisting early in the operational definition, to reach the right overall system.

5.2.3 CHART OF TORQUE vs. SPEED, Hydraulic Compared to A.C. Electric Variable Frequency

The following plot is an idealized comparison of a hydraulic "closed-loop" drive with a 2-to-1 "horsepower limiter" type control, to a typical variable-frequency electronically controlled drive with the frequency enhanced beyond the "base" 60 Hz. Both types provide 100% rated torque from "zero" (or "creep") speed up the the "base" or "knee" point. Both types show a fall-off of available torque, as the drive is "pushed" or "enhanced" above that base point.

With the hydraulic system, the provision of addition pump input power will allow a "corner h.p." drive, where there is no fall-off of torque. With an H.P. Limiter hydraulic design, it is important to select a pump with enough displacement to provide the maximum flow rate, at the reduced pressure.

Electrically the light-load maximum motor speed will usually limit how far the frequency is enhanced. Motor and gear noise increases quickly above 1,800 rpm.

5.3 Hydraulic Drives

5.3.1 Hydrostatic Transmissions

The "best" approach from the individual winch viewpoint, this dedicated drive with remote electrical control of pump flow direction and volume can be very accurate. Pumps for this service include a small "charge pump" and perhaps a second small "servo pump. It is tempting to utilize this auxiliary flow and pressure for other functions, such as auto-brake release, but a small separate electrically driven brake control pump will better serve in the long term. If charge pressure is not maintained, the main pump will lose stroke and sag down in volume and the winch will slow for no apparent reason. A separate charge-pressure gage is a useful auxiliary at each control station.

By adding a variable displacement winch motor, the output speed can be raised considerably, although with reduced line pulls. Here again, the "H.P.= k" hyperbola above a base condition is the theoretical result. Electronic digital control can blend operation of three pumps and three motors into a seamless system, such as that required for a "Traction Winch" package.

When designing a closed-loop with a charge pump, it must be remembered that the charge pressure is seen on the return side of the motor, with a corresponding reduction in the motor's pressure differential (& therefore torque output and winch line pull.)

One vital capability of any variable-displacement pump is to provide a FIRMLY DEFINED AND FIXED zero-displacement condition. Hydraulic Power Units (HPU) are often left operating during portions of a deployment when the winch drum is to be stopped. If the pump is even fractionally "on-stroke" the winch will slowly creep, without alerting the crew. (We have participated in the hour's-long task of manually re-spooling a winch room full of slack wire, hand over hand. This is to be avoided.)

Motors and pumps have defined catalog efficiencies; often separated into "torque efficiency", (pull) and "volumetric efficiency" (speed). Hydraulic drives will almost always require higher ship's primary power than will electric drives. The energy required to push the fluid through the pipes and hoses is the main difference, and it is both variable and awkward to estimate. These fluid losses add directly to the electrical and mechanical losses.

With a "unit-mounted" and short-plumbed winch package, piping losses are small and testable. A fixed winch with a remote power supply is at the mercy of the piping crew at the installing shipyard. There is a non-literal but illustrative "joke" which claims that NINE ELBOWS EQUALS ONE PLUG. Formed stainless tubing with long smooth radii and ample diameters (for low fluid flow velocities) is the most power-efficient and the most costly approach. Anti-vibration hoses should be installed at pumps, motors and primary valves.

Fluid velocity is a good measure of a piping system's design. The relationship is another of the standard formulae:

"V" (ft/sec) = "Q" (ft-cubed per sec)
divided by "A" (flow-area in square feet)

Often-used target values of fluid speed are:
- 15 ft/sec for supply lines (w. 20 fps being tolerable)
- 10 ft/sec for return lines
- 5 ft/sec for drain lines

Both legs of a closed loop can be the high pressure side, (even if the only "payout-direction" load is created by an auxiliary warping head...) and must be piped symmetrically. Reservoirs can be small, since they supply only the charge pump flow, but individual applications require caution in this area. A small tank may require heat-exchanging, where a larger tank may radiate enough heat to reach a balance.

5.3.2 Open-Loop Piston Circuits

The piston pump's output returns to the reservoir rather than returning directly to the pump's suction port, as in a closed loop. The pump suction is from the reservoir. Charge pumps are usually not involved. Return piping can be of lighter scantling, and the filtration is handled in a different manner. Reservoirs should be large; sized for two or three minutes of the maximum flow rate.

5.3.3 "Header & Branch Circuits

Many R/V's have large numbers of hydraulic motors and cylinders doing a variety of tasks. The opportunity to run dead-ended "pressure" "return" & "drain" header piping is appealingly simple.

Each functional drive element connects to all three headers. Control is via various types of valving, usually termed "proportional." Valves are available with
integral flow-limiting, direction control, and accurate flow metering for functional speed control. One pump set, (often with a back-up set for redundancy) uses pressure-compensation to hold maximum pressure at zero flow in the supply header until a branch line is opened.

It is not logical or economic to assume that every winch or cylinder will operate simultaneously. Coring winches are inactive when the Anchor Windlass is in use. The challenge to the operator and architect is to define how many and which functions might operate simultaneously. Until this decision is made, the capacity of the pumping system cannot be determined.

5.3.4 Simple Vane Pump System

Low cost vane pumps can provide fluid to several machines, by using individual manual throttling and reversing valves which have their pressure ports open to the tank port in the off position. The "tank" port piping can be connected to the pressure port of the next valve downstream, and finally back to the tank. Thus an "open-series-circuit" is created. Valve selection must include the ability to accept system pressure at the "tank" port. Only one of the several machines on such a series-circuit can normally be operated at a time, but this is not a hindrance if it fits the operating pattern.

Another circuit option is to provide a branching series of six-way selector valves which can route a single pump's flow to a number of working locations.

When two vane pumps are piggy-backed, with the same or differing flow capacities, the opportunity exists to provide two distinct flow values. One pump is fitted with an "unloading" valve which "dumps" to tank at a selected signal pressure and continues at a low-loss threshold pressure in the order of 50 psi. The second pump has a normal higher pressure relief valve.

As long as the overboard load is below the dump pressure, the combined flow provides the maximum speed. As the applied load creates the unload signal pressure the flow and machine speed drop, and at the maximum pressure, stalling takes place. High speed and high pull can thus be provided; not simultaneously, but with lower input power.

A number of "two-speed" hydraulic motors are available, with equal or differing displacements. As an alternative two winch motors can be valved & piped for either "Series-Parallel" or "One-Motor-Two-Motor" operation to provide a "high-low" two-range winch response.

Unexpected speed changes can surprise and endanger a crew when sudden load changes occur.

These combinations can provide a four-range winch drive. When controlled by a manual reversing valve with good throttling characteristics, a low cost and quite flexible system can be provided. The "seaman" on the valve is totally responsible for the accuracy of winch motion in the critical load locations.

6.0 WINCH CONTROLS

Variations in control system range from an operator standing next to a winch with his hand on a manual reversing valve, to that same operator in a cab or the wheelhouse using a PC with a touch-screen or a mouse which manipulates the entire ship-suite of overboard handling equipment.

Maintenance considerations suggest that control systems be design as simple as possible, however, many tasks demand complex controls. The massive "machine" which rides the R/V "Atlantis" A-Frame to safely deploy and recover "Alvin" does not lend itself to simplicity. A-Frames and booms require their own controls that add to the required operator skill level and to his "busyness."

Most control systems now are blends of electronic, electro-mechanical, electro-hydraulic and hydro-mechanical elements, with air controls also making their contribution. The common features of a proper control sub-system, whether primarily electric, hydraulic, or air, are:

6.1 Precision

The three load locations demanding the greatest precision are at the water-plane, at the deck, and at or near the sea-bed, such as when coring. Whether the man-machine contact device is a potentiometer knob, a joystick or a PC mouse, the load must be locatable at extremely slow creep speeds, with very fine position increments. Ideally, the control should be able to place the payload onto an egg, without cracking the shell.

Most winch systems include a spring-set automatic "parking" brake. An important element of precise control is the timing of this brake's set and release action. Present technology provides a variety of signals which will allow a drive's torque to build up gently to pull slack, overcome static friction and the payload's weight and only then release the brake. Similar delicacy of timing is needed in setting the brake.

Electric winch drives have their advocates, utilizing the arsenal of electronic and computer-based controls. A seemingly equal number of designers prefer to apply electric and electronic controls to the strokers of variable displacement hydraulic pumps. The choice can hinge upon the rest of the equipment on the ship. Traction winch systems have all been hydraulic, and regularly provide precise action.

6.2 Smoothness

The old multi-step DC control systems provided coarse steps, using five levels of grid resistance. Commutator-type lever switches provided up to 16 points.

Motor Generator Set drives could provide variable speed control. Modern SCR-DC and AC-VF drives are stepless and completely smooth between creep and the maximum design speed. The higher-level hydraulic control packages have the similar ability, with perhaps somewhat more initial tuning and periodic maintenance required. (The inside of an electric wire is a "very clean" environment, whereas achieving and maintaining a clean hydraulic system has often been a challenge.)

6.3 Functional Clarity

A variety of guides and standards are available which purport to define the semantics of control definition and labeling. In reality the variety of functions appears to stay ahead of the "standards" and requires thought and excellent communications between the manufacturer and the operator.

One control which can be cited as almost universal is the bright red "Emergency Stop" or "E-Stop." Almost every panel provides one oversized button which is pressed (or bashed) to abort an operation in the minimum time. Even here, different systems will require properly sequenced detail actions within a control package, to achieve the quickest shutdown without shocking the payload and wire, or leaving the control box in a non-resettable condition.

6.4 Multiple Stations

If for no other reason than permitting a technician to operate a winch during maintenance, it is desirable to fit a "local" or "at-winch" set of controls. Many working deployments are managed from a weather-protected cab which is located to provide the operator a clear view of both the winch being used and the overboard point. Aboard smaller vessels, this sheltered station may be in the wheelhouse itself.

Semantically, a station which is away from the winch itself is best referred to as a "remote" location. "Local" implies that the man is at the machine and able to react immediately to any malfunctions which might occur.

When winch machinery is inside or below deck, the operator visibility of the overboard point takes priority. Video cameras and monitors should clearly show the state of the

wire spooling onto the winch drum, and instruments monitoring the drive-condition should be available to the operator.

Station selection has two main formats. The least desirable provides a "Give-It-To-Me" button at every station, accompanied by lamps which define the controlling point. This arrangement sets up the possibility for two would-be operators conflicting with each other.

Except in special situations the better approach is to provide a single station-selector -- again with lamps to indicate the active station. This may require additional walking or communication, but it gives control to one person. The "E-Stops" at all stations must remain active.

7.0 FAIRLEADING AND SPOOLING

A major feature of a winch's success is how smoothly the "line" is spooled onto the drum. An even and level "lay" minimizes line wear and adds to the accuracy of the instrumentation by providing a known number of wraps per layer. For any tension member which retains an essentially round cross section as it wraps, the "Lebus" proprietary drum shell can make the major difference between a smooth spooling to be admired and a "hill-and-valley" spooling; possibly tolerable, but likely demanding frequent fairlead adjustments, to avoid wear-inducing piling, and in the worst case, "back-&-overs" which can lock the line into place. If a machine must handle a variety of lines, the interchangeable drum, each with a grooved shell is often the right answer.

If the winch location provides a 20-to-1 or greater ratio between the drum's face width and the distance from the drum center-line exit-tangent to the nearest (& centrally aligned) fixed guide point, a mechanical fairleader theoretically should not be needed at all. However, in almost every case reality trumps theory, and a fairleader is indispensable.

7.1 Fairlead Drives

Two opposing fairleader design approaches have attracted their own adherents. The simpler design mechanically drives a "diamond screw" from the winch drum hub. The "shuttle" (cam follower, butterfly, etc.), which rides in the bi-directional long-pitch screw groove, pushes the traversing fairlead head back and forth. A simple hand-wheel and jaw clutch allows for initial head positioning and any adjustment that may be needed.

The other style is based around a single-thread lead-screw which is separately powered and reversed by various forms of servo-drive and switching, and which uses various forms of cable-position sensors to tell the drive where it should place the fairlead head.

As is normal, each type has its own plusses and minuses. For this description, we elect to use the term "Putter" for the diamond screw type, and "Chaser" for the servo-drive type.

7.1.1 Diamond Screw "Putter" Type

To succeed, this drive must be designed with a exact knowledge of the line's loaded diameter -- "Lebus" normally tests samples of actual wires or cables to provide this data. The relationship between the face width of the winch drum and the "turn-around" stroke of the diamond screw must be correctly laid out. The exact practice is hard-won knowledge and is often held as proprietary.

In effect, the fairlead head is going to be "Put" the wire in perhaps 3000 exact locations (100 wraps by 30 layers). This requires a high degree of numerical precision in the drive chain ratio, and benefits from the application of a custom pitch-matched Lebus shell.

Bare-drum spooling (i.e., without a grooved shell,) can work well, however the inter-wrap air-gap is determined by the crew person defining the barrel layer with a stick and a hammer, and the designer must guess at a wider air gap when determining the number of wraps per layer. The "Lebus" shell allows a closer air-gap and determines the exact number of wraps on the barrel layer. That same value will apply to each layer, if the intent is met.

For most research winch applications, one or two different line types will cover years of its work. A pair of interchangeable drums and a quick-change set of drive sprockets will maintain the needed matching. Working experience with the "Lebused Putter" fairlead has been good to excellent, and maintenance is reduced primarily to normal bearing and guide lubrication.

7.1.2 Servo "Chaser" Type

This form of level-winding is intended to accommodate any size of line onto the same drum, since its sensors are designed to tell the servo drive where the line is, and the separate screw drive then places the traversing head at that location. In practice, they are frequently also matched up with a "Lebus" shell for a known line diameter.

Impressive design ingenuity has been observed on many variations of the servo fairleader. Excellent results have often been achieved. Since this author's firm does not use the "Chaser" fairlead, the only reasonable comment is to note the increased number of parts involved and the apparent complexity of the overall approach.

7.2 Rollers and Sheaves

Each research wire, cable and umbilical has its own bending-radius requirement. If a long & centrally-aligned line lead is available and the cable's direction change at each end of the drum can be less than 3 to 5 degrees, a simple set of vertical and horizontal guide rollers may be adequate. With large roller diameters and the small wrap angle (a "kiss-bend"), the low-cost roller head has sometimes been sufficient. With a rollers-only fairlead head, all cable parameter instrumentation must be taken from an off-winch sheave.

The more frequent design solution mounts one or more sheaves directly on the traversing head. One arrangement provides two guide sheaves on either side of a central "metering sheave." The cable payout and tension sensors are incorporated with the central sheave. Looking at a side elevation, the tension sensor axle-pin sees an always-vertical direction vector as the wire exit angle varies up and down.

A pair of adjustable-angle rollers beyond the downstream guide sheave insures that the line enters the sheave suite in a straight line. These rollers can be adjusted to cover a range of up or down lead directions to the overboard point. If deck space requires the winch to be close to the first guide sheave, the entire fairlead assembly can be designed with a built-in up or down angle.

7.3 "Open-Lay" A Speculation

Many cables and umbilicals are not firmly round in cross-section. The attempt to spool these in the normal manner can be frustrating and can cause a deployment to fail. Such failures can result from the cable becoming out of step with the fairlead and creating an "over-and-back," or if the cable lay becomes "loose" the exiting lead can "pull-down" through many layers and lock up.

One simple solution to both problems might be borrowed from the work boat fleet which is increasingly using "soft" "Spectra" and "Plasma" type braided lines in ship-assist and ship-escort assignments. Working with a bare (non-Lebus) drum, the traverse rate of a level-winder's head can be sped up by the substitution of a smaller driven sprocket at.the diamond screw. By tripling the rate above the normal, an "open-lay" is achieved whereby the "air-gap" is twice the nominal width of the line. This is sometimes called "universal spooling."

This is readily illustrated by the reader spreading his fingers and laying one hand atop the other. A large number of cross-overs take place and because of this "under-bridging", pull-down is prevented.

With many cross-overs, the angular change at each becomes small. The down-side to this layout is an increase in contact pressure at each cross-over. For some cables this may not be a problem. For others it may rule out the concept. Recall that for a regular "wire-lay" there is always one crossover per wrap, (or two with a Lebus shell). They are at a flatter relative angle with more length spreading the contact force.

It will be intriguing to see if such an "open" or "universal" lay can alleviate current and future spooling problems for particular forms of tension member. Where it will function, the need for grooving and fairlead precision go away, and cost would be reduced.

INSTRUMENTATION

The research winch provides three of the cable data parameters which computer collector systems require -- Line Tension, Amount Of Line Payed Out, and Line Speed. In some cases an operator may wish to know the approximate angle at which the wire enters the water. Winch drive power demands (speeds, amps, pressures, etc.) and condition indicators such as various system temperatures can also be added.

While the three primary cable values can be taken from the winch drive package, r.p.m., amps or psi are only rude indicators of drum speed and torque, and a layer-compensation chart must be used. A much more reliable approach is to utilize a direct-reading cable sheave as the sensor "drive." The "measuring sheave" can ride the traversing fairlead head, or it can be a separate downstream sheave -- preferably with a known wrap angle.

Signal Generation

8. Cable Tension

Strain-gauged sheave axle-pins are a specialist product requiring close cooperation between the winch builder and the pin supplier. The signals which sense the bending of the pin under varying cable tensions are very low-level. To improve reliability many pins now provide integral amplification electronics in an enclosure at the pin's end.

Knowing a tension sheave's cable wrap angle is a major advantage. While it is possible to use an overboard sheave for this purpose, the load vector seen by the pin is constantly changing. "Rube Goldberg" wire followers and potentiometers can be used to compensate, but this choice is far down the list.

8. 2 Cable Length Payed Out

The distance that the wire travels in one sheave revolution is readily translatable into feet or meters paid out. The addition of time results in the line speed in feet or meters per minute. One basic method involves a pair of marinized proximity sensors. (A pair is necessary in order to sense the wire's direction or travel.) These can react to machined spots on a sheave's ribs, but much better resolution is provided by providing a slotted disc with more "interruption" points.

The best results are provided by employing fully housed "Optical Encoders" with step-up gearing from the sheave's hub. Very high accuracy's can result.

8.1.3 Cable Speed

Once the length-reading hardware is in place, the count pulses allow production of a cable velocity signal to be an electronic "no-brainer."

8.1.4 Cable Exit Angle

While criticizing vector-correction angle sensors as part of an overboard sheave's tension-measuring action, such hardware may be needed for the different purpose of defining the angle at which the wire is either leaving the ship or entering the water. The fully deployed overboard frame is likely the preferred reference point. A wide variety of sensing tools can be envisioned, and each could work well in flat water or perhaps in long swells. Given the Sea States in which the ships and crews are being asked to do science, this angular information would seem of secondary reliability. On the other hand it is a risk to bet against the potential power of gyros, lasers and computers.

8.2 Cable Slippage

The length and velocity information is contaminated by line slippage relative to the measuring sheave throat. One observed remedy has been to use a "rubber" or similar material to improve the grip on the cable. This generates a "wearing surface" involving maintenance, and with wear, small changes in the working pitch diameter of the cable can result. This change biases the data quality.

Most research winches do utilize "Lebus" shells matched to known cable diameters. One builder provides a three-piece measuring sheave with a hard "T-1" (or similar) steel center plate and an demountable outer sheave side plate. The o.d. of the replaceable center plate places the pitch line of the cable at a known and convenient diameter. Typical pitch circumferences are one-meter, 1-1/2 meter, two meter, etc. Such initial "natural" selections can ease the system designer's thinking process.

Since the cable's diameter is known, the center plate's thickness can be ground to insure that the machined throat sides provide a "light kiss grip" on the cable. Watching the length meter return to "zero" after a multi-thousand meter cast is normal and gratifying, since slippage control has been achieved.

8.3 Displays

PC screens can be utilized to directly provide the winch operator with the information about what is going on with his overboard cable. Additional information such as that sent from payload "pingers" can expand his awareness. The PC approach has so far been awkward for on-deck local control stations.

Presently the preference remains for dedicated digital and analog displays of the three primary line values. A variety of digit types and sizes are available, and waterproofing is available. Particularly with the tension value, the addition of a naturally damped analog dial can provide the operator with a more useful sense of the overboard load than attempting to focus on a "jumping" string of digits.

These electronic displays provide connection points for the standard variety of electronic cabling to move the data onward to a ship's logging computer. Integral key-pads can facilitate the setting of various alarms such as high or low tension, near-surface load location, etc. These settings can talk back to the winch drive and provide automatic slow-down or other responses.

FITTING THE WINCH TO THE SHIP, AND PORTABILITY

9.1 The Basic Suite

Most mid and large R/V's are outfitted with a basic suite of large, medium and small winches to bracket the predicted requirements of the scientists. The smaller boats often omit the mid-sized machine. This equipment-matching is major part of cruise planning.

Ideally, with a new ship program, the winch people are brought in at the layout stage. This permits engineered and correct relationships between the winch line leads, the overboarding frames or cranes, and often the sheaves that must take the cables "from here to there." When a winch is within a working space or even below deck, this early involvement upgrades from a convenience to being critical. The ability to customize large winches to their available spaces has been an important selection factor in many instances.

A ship's basic winch suite can be welded down to suitably muscular deck insert plates. Alternatively structural subbases can be shipyard-furnished to accept hold-down bolts at the winch sills. The "turntable ring" base is the logical extension, where a winch can be aimed directly toward more than one overboard point.

Ship-Of-Opportunity Winches

In an environment where vessels are increasingly marketing their available time to a "customer-base" of marine scientists, more situations are arising where a science team will have its own packages, cable, and perhaps the full winch and drive package. Many ships outfit their working decks with a 24" grid of tapped and plugged bolt-down sockets as an accommodation means. The precision of this grid spacing has been known to vary, and the machine may require orientation other than orthogonal to the ship. The simple addition of a "subplate" by a shipyard or the institution's own shop can resolve both situations.

The unit-mounted or modularized winch package which provides its own power umbilical with a standardized plug works with the receptacle outlets that are a part of most modern R/V's. Electro-hydraulic winch packages lend themselves to this approach, whether totally self contained, or with a separate

HPU incorporating all the connecting hoses and the prime power "cord." Where an electric starter panel is required, it can be separate or fully waterproofed (NEMA-4) and integrated. The less costly dripproof panel requires a properly sheltered location.

Ship Of Opportunity winches should ideally provide integral data signal sources and display components, with standard porting to allow passing information to the ship's PC.

10.0 CONSTRUCTION

Applications exist for absolutely minimal winches intended to last for only one cruise or project. The opposite requirement is for a machine intended to perform to design specs for 30 or 40 years, with the probability of seeing service on the "next" ship, after the initial vessel is retired. Winches can be "throw-away" quickies, or full capital investments. Individual builders normally find their own "comfort zone" along this spectrum, so that a buyer will have a reasonable idea of where to go to match his needs.

The author's firm chooses to emphasize the "Hell-For-Stout" approach, although this may involve serious engineering to "build in lightness." This imposes the duty to provide machinery which can be maintained easily and which is worth a re-powering when the initial drive have lived its life. Record keeping must be complete, so that wearing parts remain available for the decades involved -- not waiting on the shelf, but quickly produced from the as-built detail drawings.

Certain basic practices lend themselves to long life. Steel fabrications which are stress relieved before machining, hold their shapes as the machining cuts are made. Integrally designed gear housings allow full design control and compactness as compared with bolted down commercial reducers. A major decision is whether to line-bore all the bearing fits or to use separate pillow blocks with shims or "chock-fast". Line boring insures repeatable reassembly during the machine's life and eventual refreshing. Anti-friction bearings are preferred over bronze bushings, at all primary shafts, including the outboard winch A-frame. Where drums are interchangeable, each drum should be fitted with its own outboard steel anti-friction pillow block, machined to defined dimensions for a positive fit.

Lubrication provisions are critical. Research winches often operate slowly for extended periods -- an auxiliary lube oil pump will maintain gear and bearing lubrication, where simple oil-bath lubrication might not. Linkage grease fittings which are inaccessible will not be serviced! The right approach is to provide heavy duty brake-type hoses which bring lube points out to ganged blocks which are handy for the crew person with the grease gun. Gear housings should have marine ball-type drain valves to allow regular condensate drain-off. Jaw-type gear-range or free-spool clutches require less maintenance than the friction type, and as seldom used elements, they are best located within the gear housing. Heavy transparent "windows" into the gear housing should be provided to aid clutch engagement and confirm lubrication. External mechanisms such as drum brakes should be heavily constructed to withstand the full input of the largest crew person, utilizing the longest "cheater bar." (Which should never be needed, given proper maintenance.) All fittings should be stainless or otherwise non-corrosive, and winch surfaces should be sandblasted, inorganic zinc coated, and top-coated with one of the many epoxy or equal coatings.

11.0 "R.F.Q." INPUT INFORMATION

No standardized form or questionnaire can properly lead to the right Research Winch being produced. Engineering communication at all stages is required to assure that result. There are basic parameters that serve well to open discussions. These include:

- a) Diameter and characteristics of the primary wire or cable, including - the manufacturer's bending radius recommendation.
- b) Length of the longest cable envisioned, over the winch service life.
- c) Planned payload's in-water weight, and something about drag characteristics, both hoisting and lowering.
- d) Hoisting speed required
- d) Type of power preferred -- electric or hydraulic.
- e) Type and amount of ship's power, for permanent installations.
- f) Type of ship's hydraulic circuitry

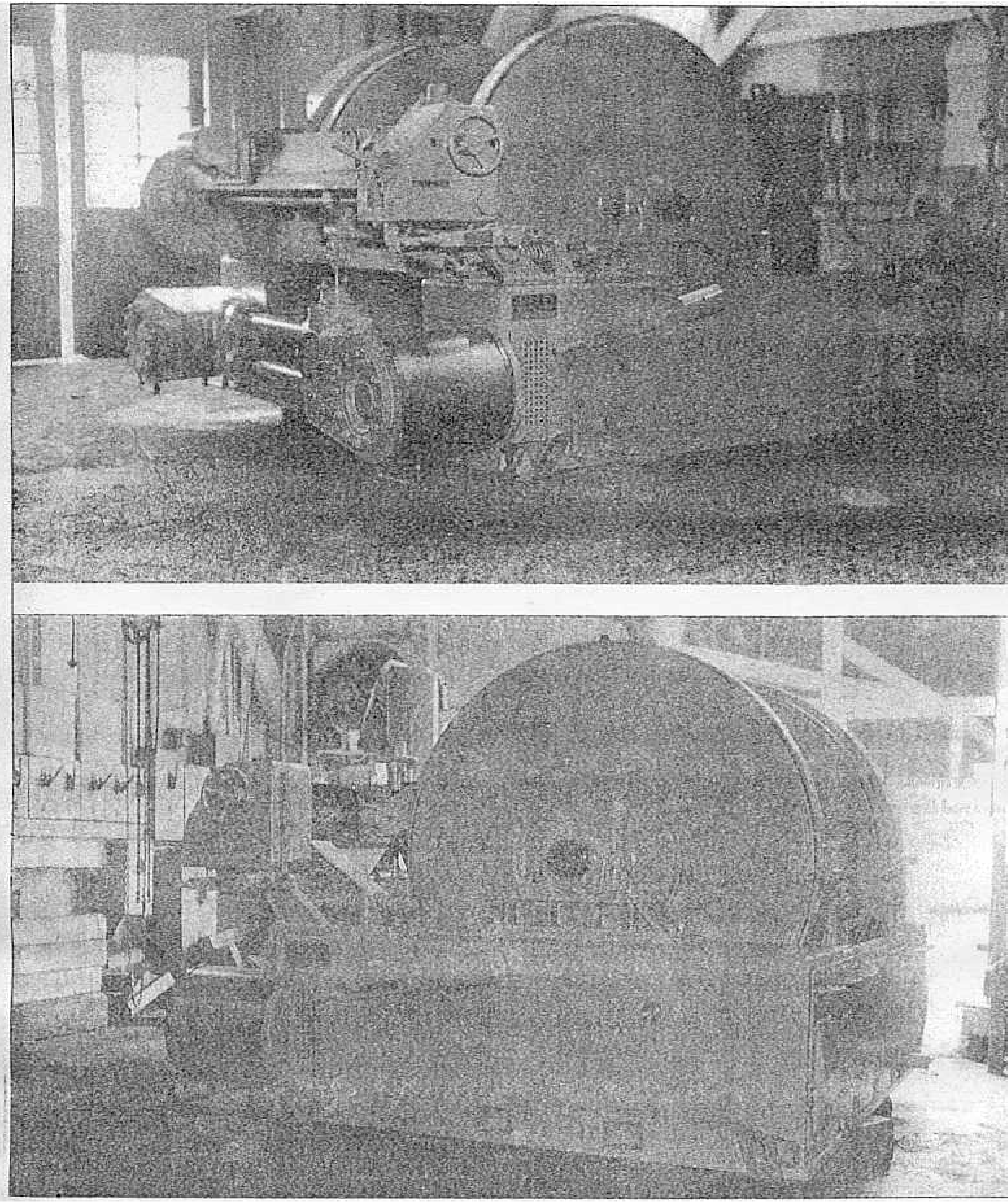
g) Vessel details, such as intended winch location, orientation, location of the overboard points, etc.
h) Number of control locations required
i) Degree of instrumentation required
j) Weight-critical circumstances which might require aluminum or part-aluminum construction.

It is not necessarily easy to gather up this much information about a new winch requirement. The buyer will often be caught in a web of conflicting preferences generated by his own people and by potential users of the ship. The necessary compromises are a normal feature of the preliminary definition "give-and-take."

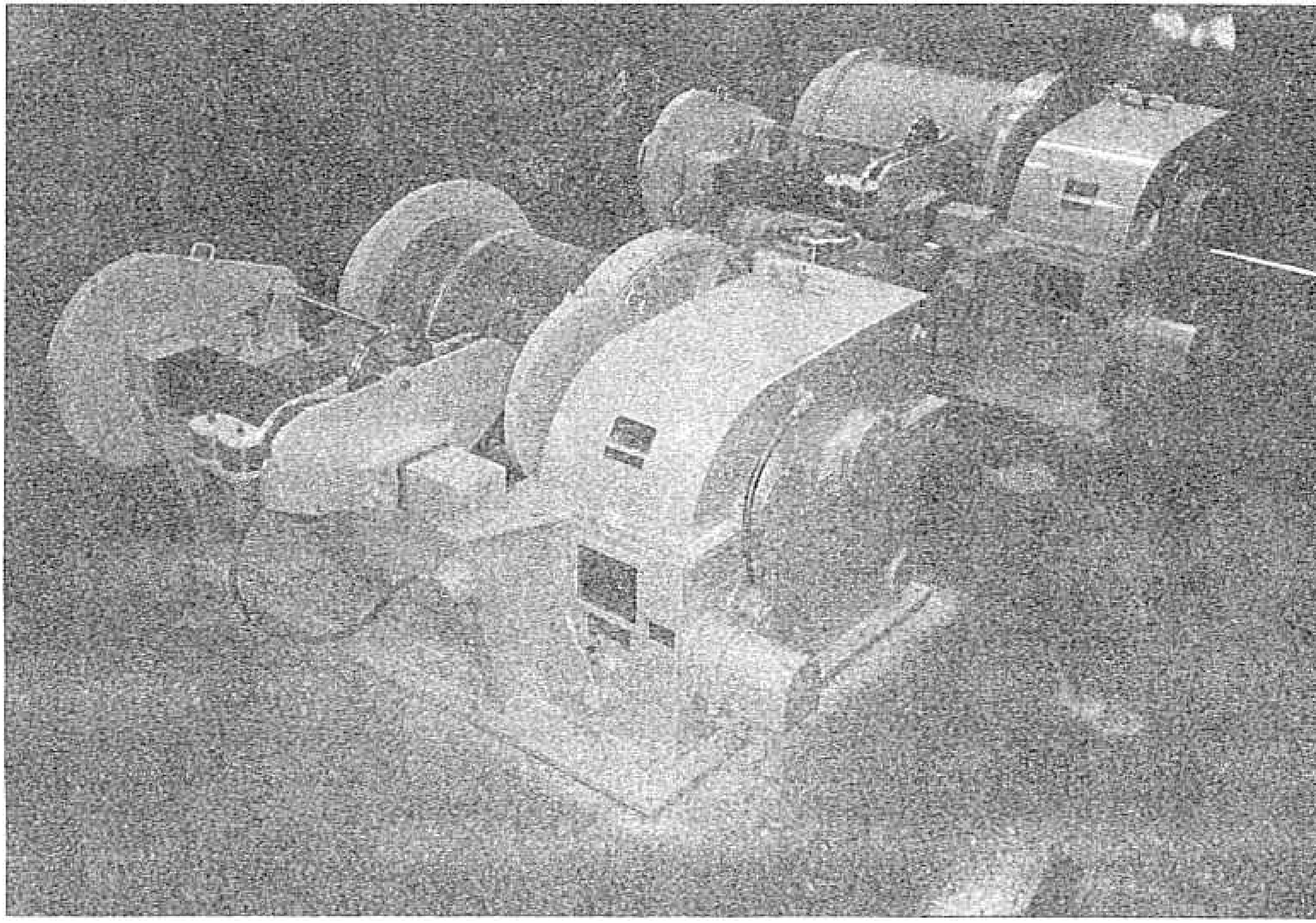
2.0 CONCLUSION

Tethered and free-swimming vehicles are adding to the kit of tools available to the marine scientist, as are buoy arrays of all types, manned submersibles, and a list of others which one can only be certain will grow and improve. The author is of the opinion that there will remain an active requirement to handle all manner of lines, wires, cables, umbilicals, etc. on powered drums. It appears equally certain that the basic tool called the "Winch" will also continue to evolve in all directions -- absorbing ever increasing degrees of electronics, computer power, and material science.

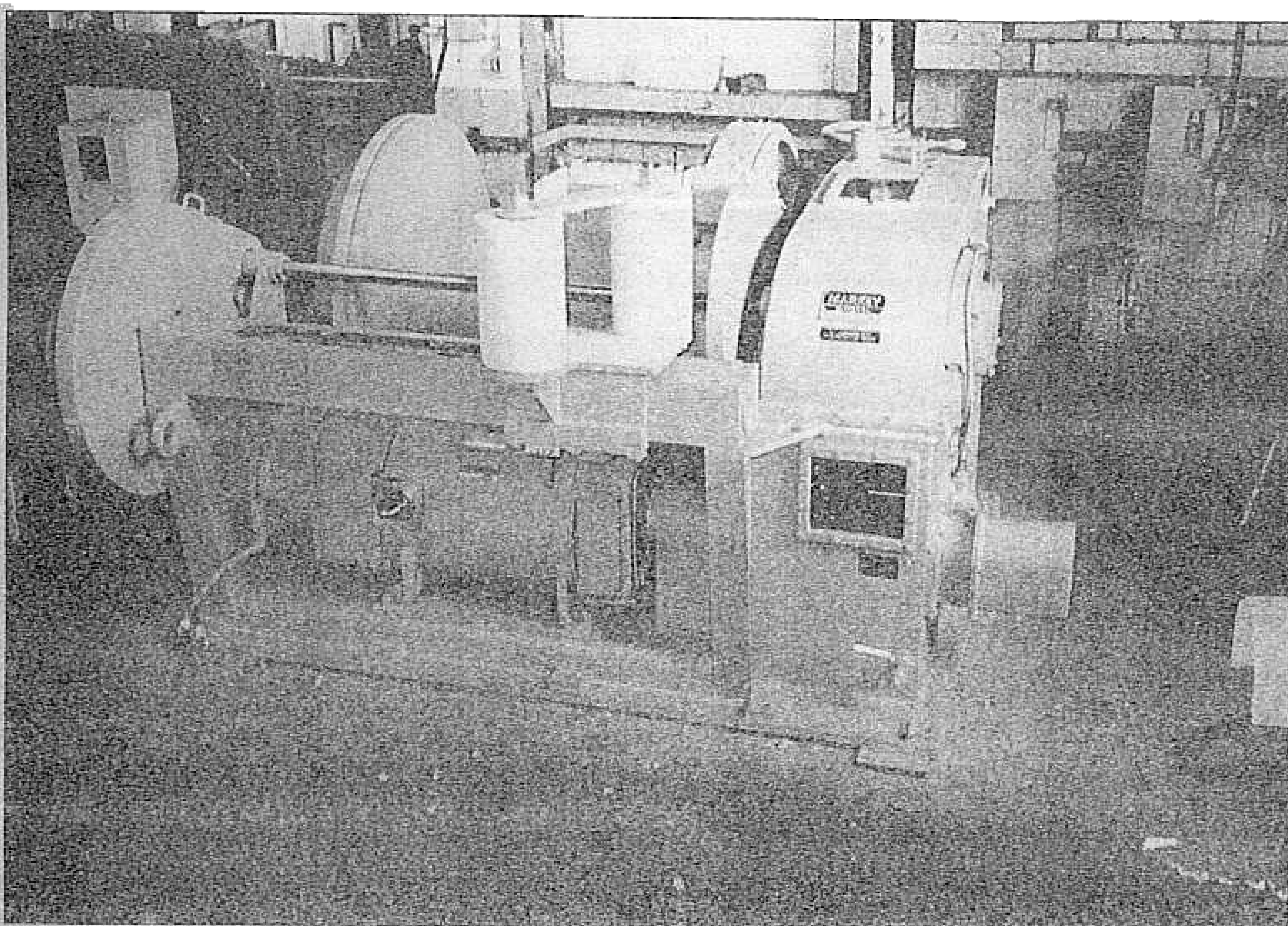
Our final opinion is that just as the Oceanographic Community remains a very diverse group of individuals, (as does the larger "waterfront" tribe), the Research Winch branch of the sea-going deck machinery tree will remain primarily custom in nature. Experience and continuity will continue to be important attributes for the owner, the architect, and the machinery designer and manufacturer.



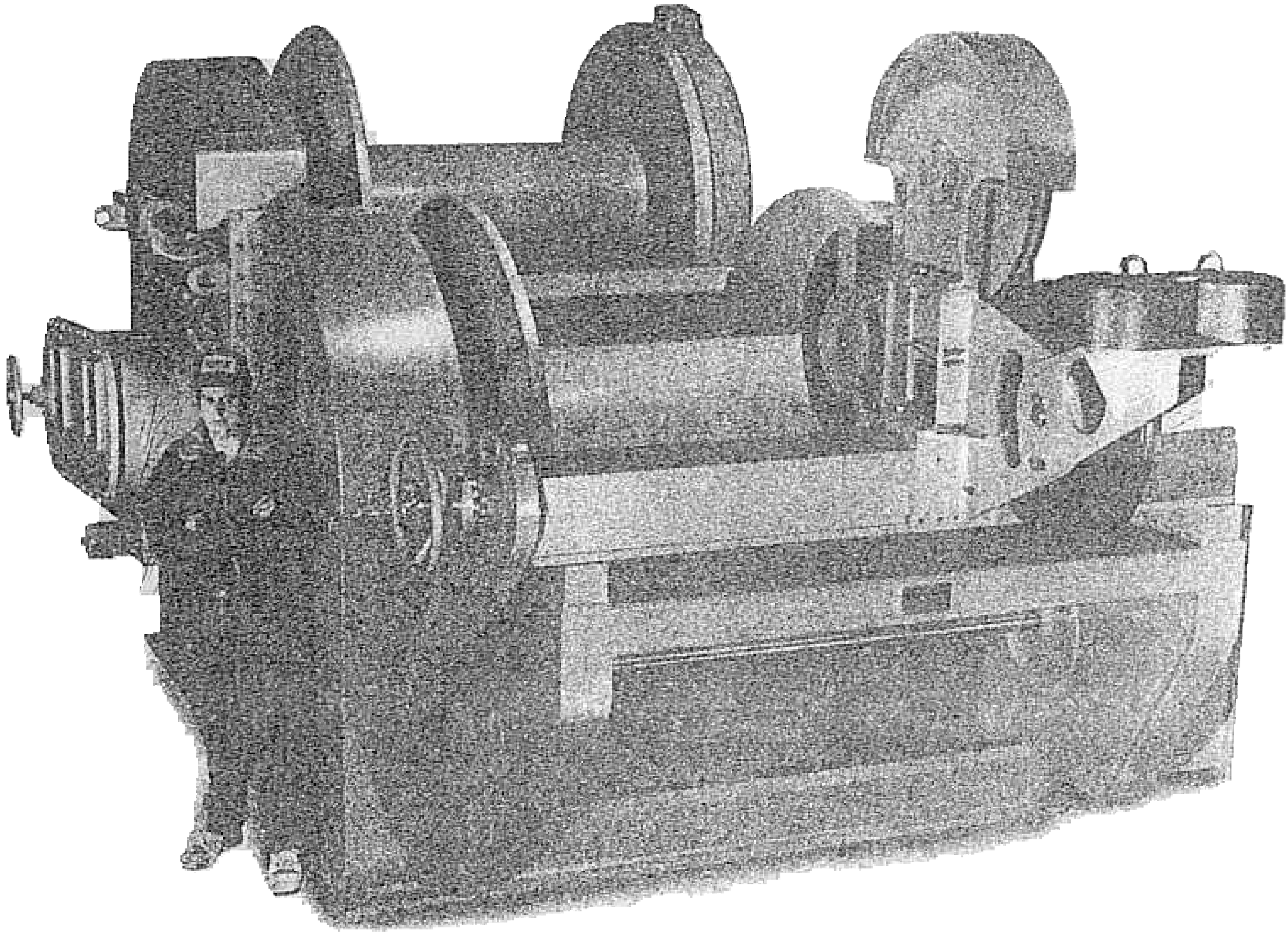
The last U.S.-built steam powered Research Trawl Winch, this DSSH-10 went aboard the new "AtlantisII" to utilize the steam from her Skinner Uniflow engines. The entire integrated engine was designed from scratch. When the ship was repowered, the con-rods were removed and a 200 h.p. electric-plus-gear drive was coupled to the crank disks.



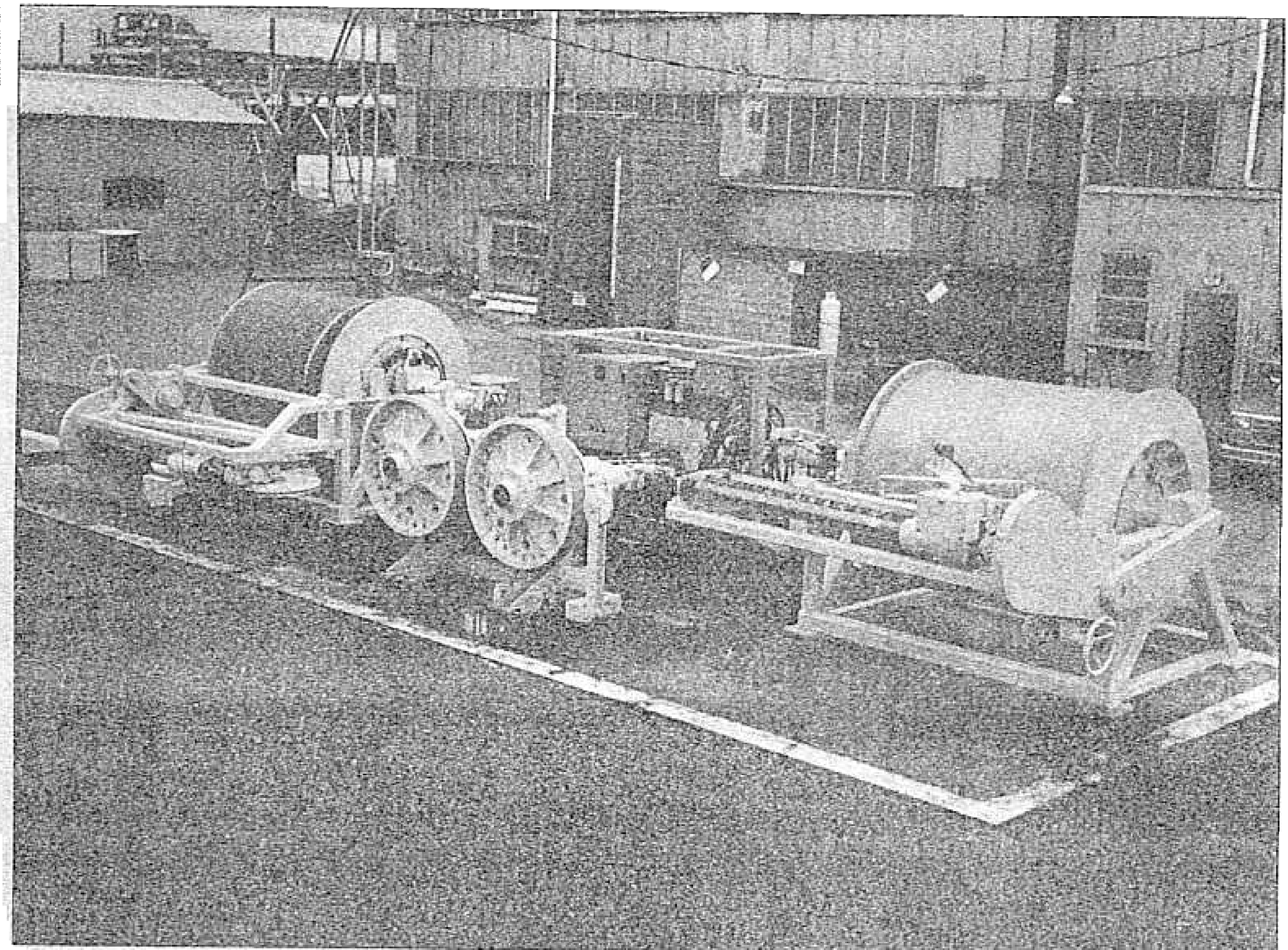
Two DESH-5 winches with 75 h.p. SCR-DC drives are shown spooled with 3 x 19 wire and 0.322 cable, ready to go The three-sheave fairlead heads show clearly. The extended enclosures coaxle with the input shaft are tachometer generators with zero-lash couplings, which are critical to the DC drive performance. “Atlantis” and “Ron R. Brown” received these 15,000 lb. machines.



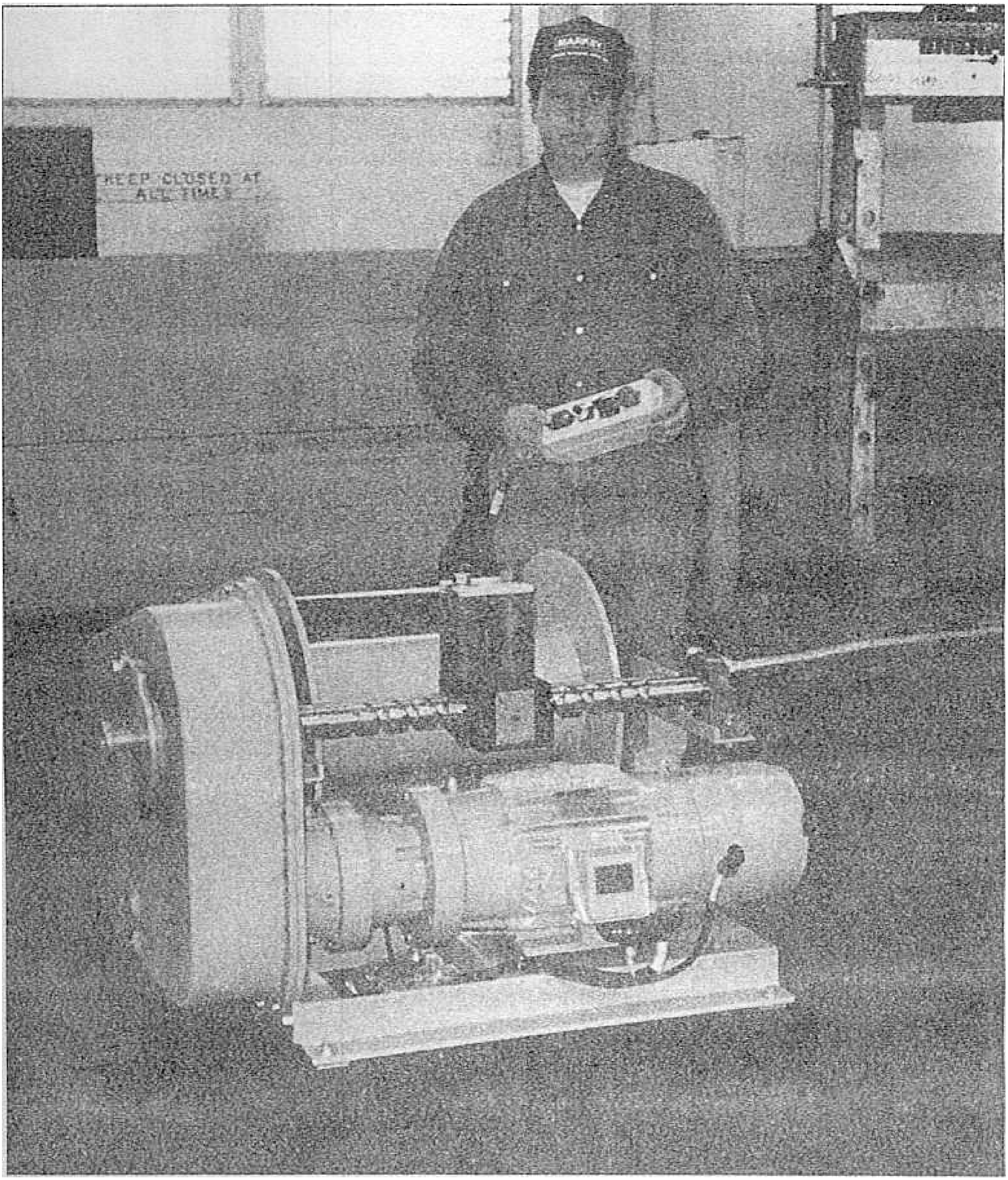
A 75 h.p. SCR-DC DESH-5 destined for "Knorr" illustrates the simpler fairlead, with nylatron guide rollers. Instrument signals were taken from off-winch sheaves. The armored feed hose from the Tuthill lube pump is visible above the tach-generator, as are the two large gear housing inspection windows.



This 150 h.p. Type DESH-9-11 AC-Hydraulic two-drum "waterfall" winch is installed below aboard "Thomas A. Thompson". (AGOR-24) The larger low drum handled 0.680 EM cable while the smaller high drum attempted to spool 9/16" 3 x 19 wire. This machine weighed 98,000 lb., with both wires



The later three AGORs (Revelle, Atlantis and Brown) were fitted with dual-storage-winch plus traction winders. Both storage drum barrels were of 48" diameter, and one of the counterbalanced 90" fairlead sheaves was 48" to handle 0.681" fiber optic cable in the future. The 3 x 19 wire drum had a 30" dia. fairlead sheave. These three components and the H.P.U. are set up for test in the winch-room orientation.



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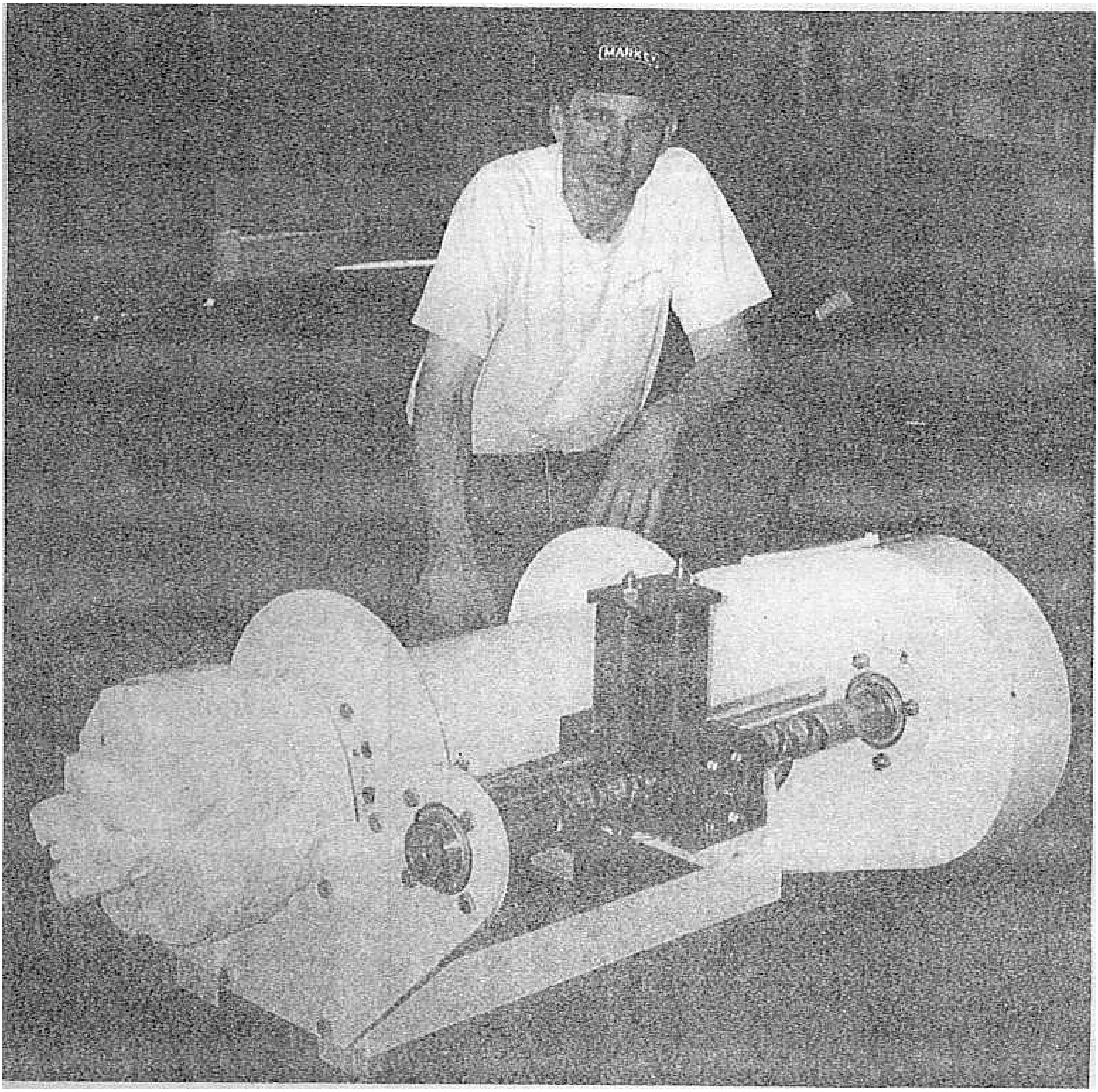
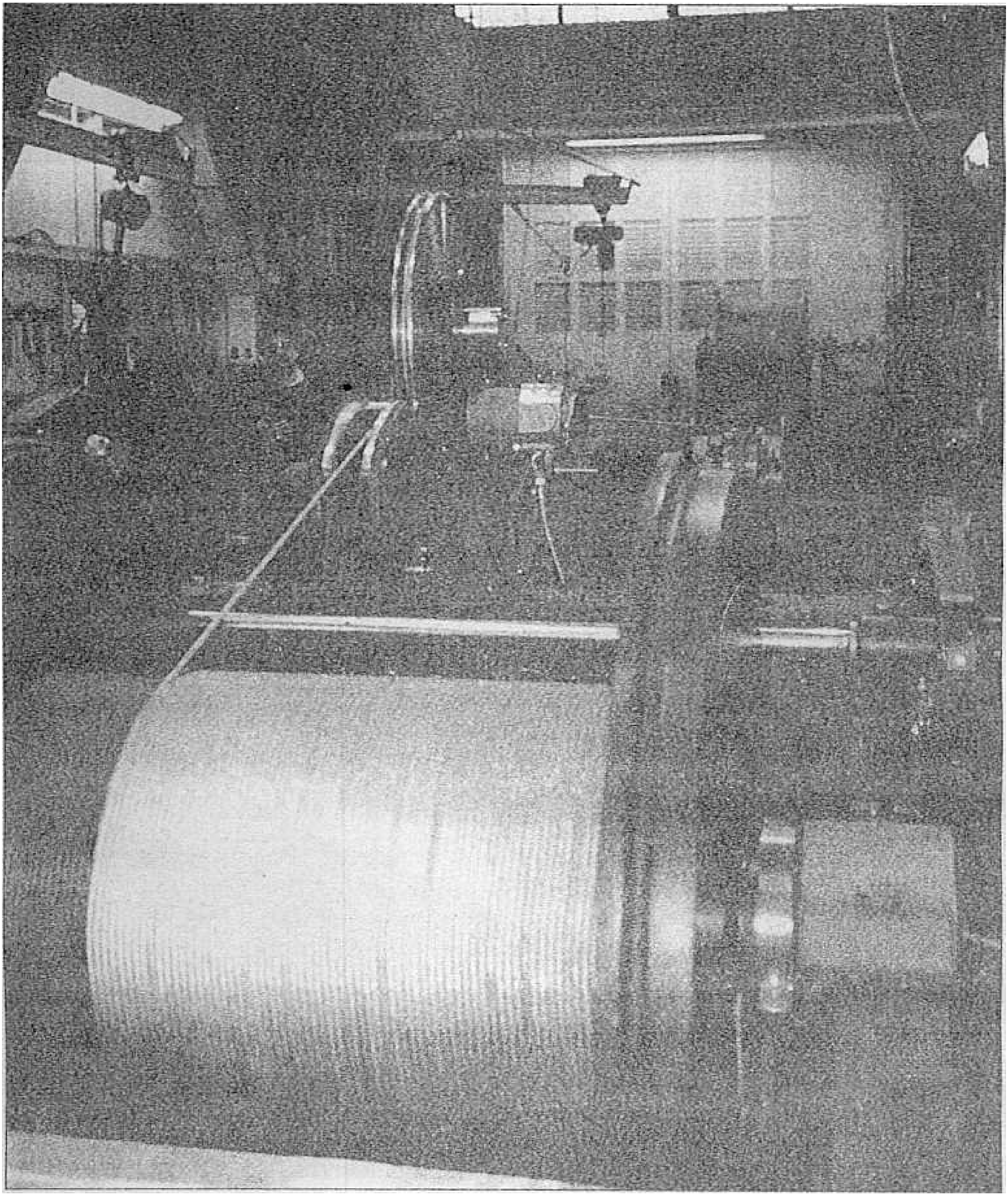


From small to smaller. This 350 lb. coaxial-drive hydraulic COM-4 was custom designed to mount on the cabin top of a 40 ft inshore yacht-type "R/V". Drum Capacity was for 400 meters of 0.322" or 600 meters of 0.257".



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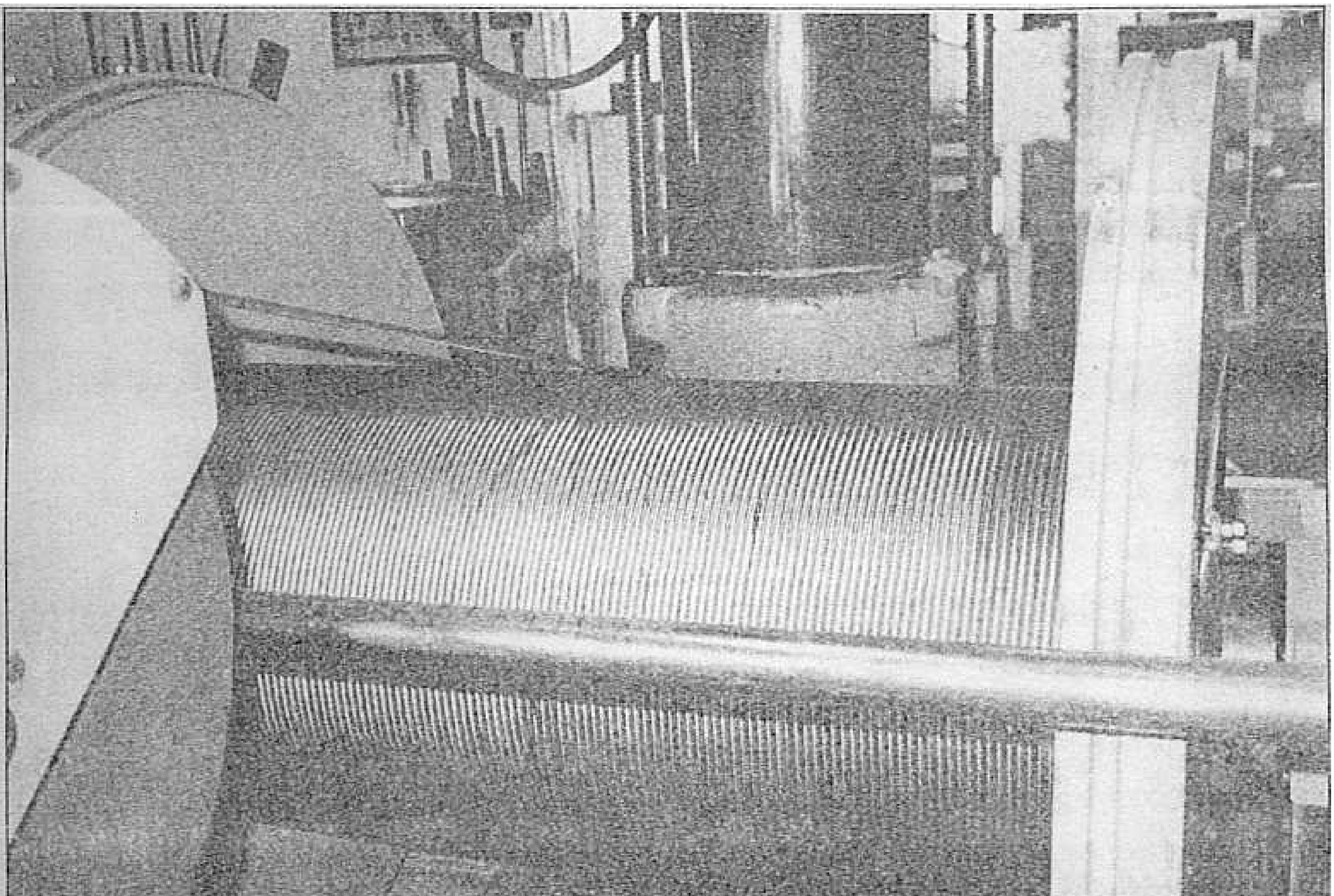
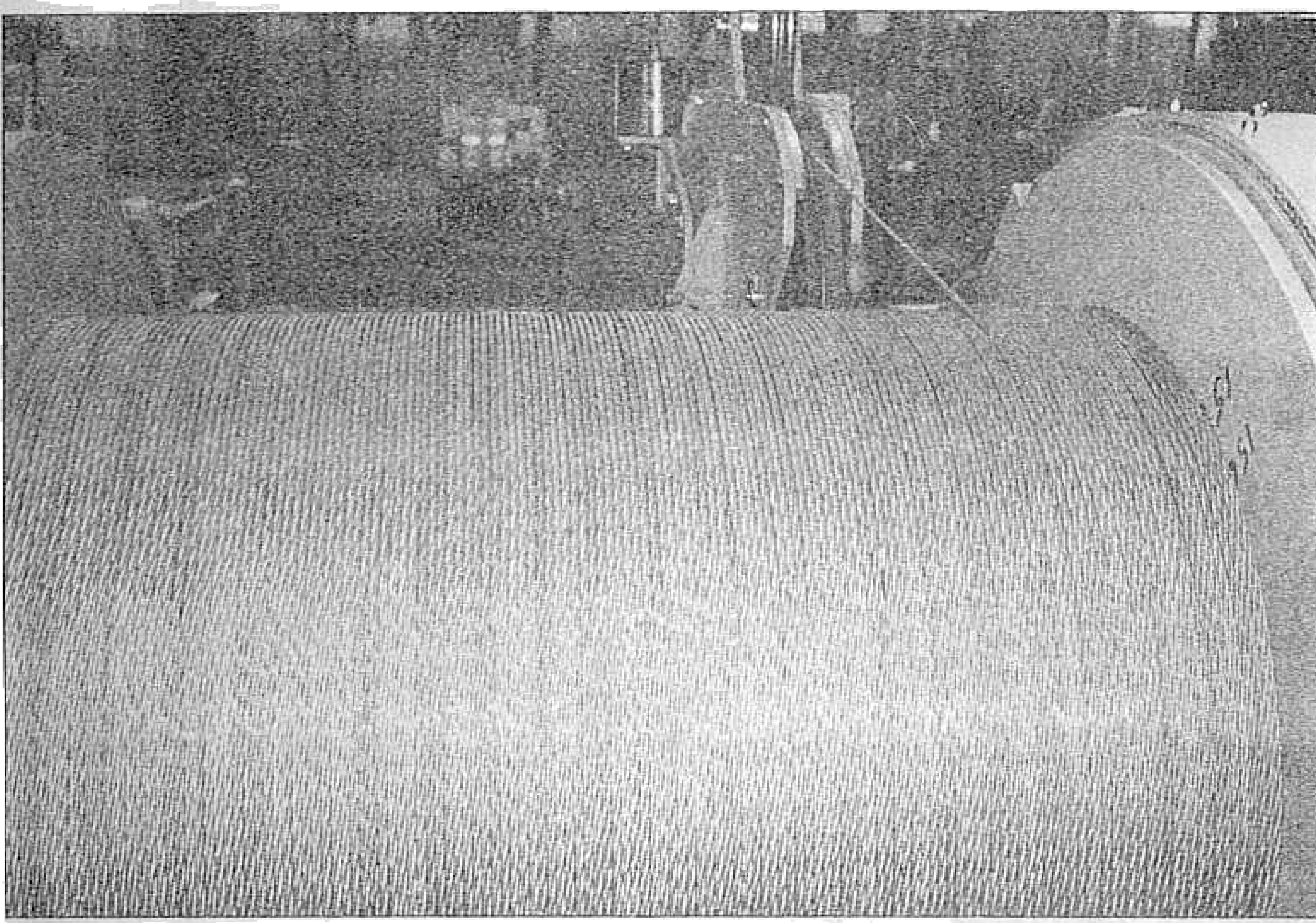


Spooling is well along the 2nd of perhaps 30 layers. Note the drum flange thickness, and its sling-groove to facilitate drum interchange.



Even 3 x 19 torque-balanced wire rope can be cleanly spooled --at least under factory conditions. The traction retarder is visible beyond the winch's three-sheave fairleader.

A typical electric winch operating panel for console installation. The in-house instrumentation display provides analog meters for speed and tension, a digital display for amount of wire out, and an additional digital unit for keypad setting of alarms, etc. The joystick controller and the system ammeter share the middle row with the bronze marine light. The large red "E-Stop" is on the bottom row.

ACKNOWLEDGEMENTS

The author's thanks are extended to a number of people who have contributed to making this chapter possible.

Bill Markey and Bob Kennard, who provided patience and training leading to an ongoing 40-plus year career at a respected Deck Machinery "design and manufacture" firm.

Cy Ostrom, Clarence Phipps, Curly Weinbrunner and all the other suppliers and advisors who added their specialized knowledge to the awareness of the variety of systems that make up a marine winch.

Henry Wickert, Joe Busch, Farrell LaTour and Barry Griffin who provided the sense of customer contact without which no amount of engineering will fly.

To each and every Fleet Owner, Marine Superintendent, Port Captain, Naval Architect, Shipyard Project Boss, Deck Engineer and Scientist who has held our feet to the fire and provided us the opportunity to contribute to their ship's success.

To Blaine Dempke and Bob LeCoque "Jr" who are this firm's virtual fourth operating generation, and who provide the decades of experience and energy to keep this firm doing what it knows how to do, and expanding on that knowledge.

And to Allan H. Driscoll, the Office of Naval Research and the National Science Foundation, along with UNOLS, who provided the Oceanographic Community with the "Green Book", the "Yellow Book", and this third edition -- whatever color it may turn out to be.

Michael J. Markey, p.e. 2000