

Aug. 27, 1946.

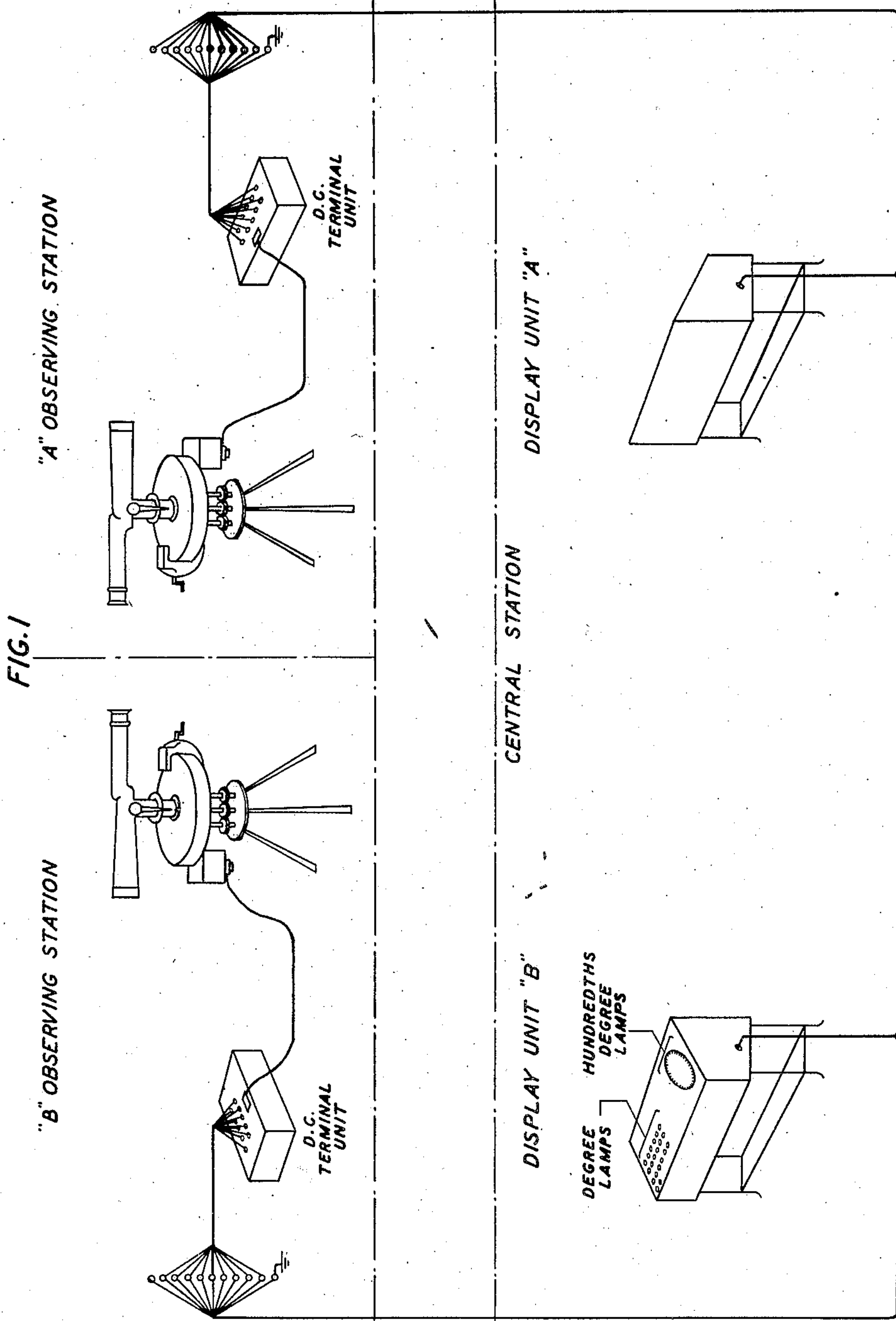
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2,406,384

DATA TRANSMISSION SYSTEM

Filed Nov. 5, 1942

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

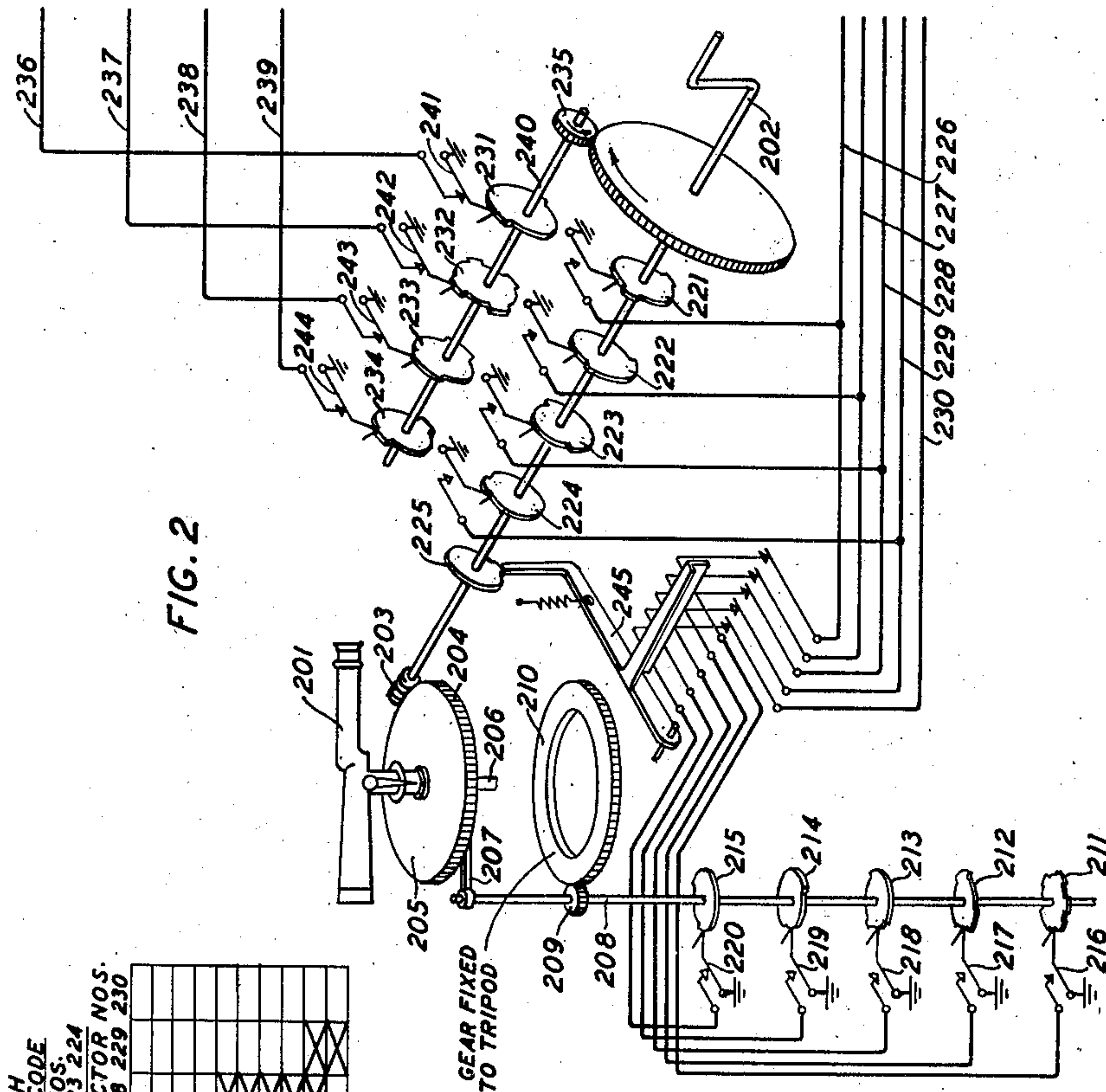


FIG. 2

FIG. 5

TENTH DEGREE CODE		CAM NOS.		TENTH DEGREE CODE		TENTH DEGREE CODE	
221	222	223	224	225	226	227	228
229	230	231	232	233	234	235	236
237	238	239	240	241	242	243	244
245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260
261	262	263	264	265	266	267	268
269	270	271	272	273	274	275	276
277	278	279	280	281	282	283	284
285	286	287	288	289	290	291	292
293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308
309	310	311	312	313	314	315	316
317	318	319	320	321	322	323	324
325	326	327	328	329	330	331	332
333	334	335	336	337	338	339	340
341	342	343	344	345	346	347	348
349	350	351	352	353	354	355	356
357	358	359	360	361	362	363	364
365	366	367	368	369	370	371	372
373	374	375	376	377	378	379	380
381	382	383	384	385	386	387	388
389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404
405	406	407	408	409	410	411	412
413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428
429	430	431	432	433	434	435	436
437	438	439	440	441	442	443	444
445	446	447	448	449	450	451	452
453	454	455	456	457	458	459	460
461	462	463	464	465	466	467	468
469	470	471	472	473	474	475	476
477	478	479	480	481	482	483	484
485	486	487	488	489	490	491	492
493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508
509	510	511	512	513	514	515	516
517	518	519	520	521	522	523	524
525	526	527	528	529	530	531	532
533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548
549	550	551	552	553	554	555	556
557	558	559	560	561	562	563	564
565	566	567	568	569	570	571	572
573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588
589	590	591	592	593	594	595	596
597	598	599	600	601	602	603	604
605	606	607	608	609	610	611	612
613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628
629	630	631	632	633	634	635	636
637	638	639	640	641	642	643	644
645	646	647	648	649	650	651	652
653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668
669	670	671	672	673	674	675	676
677	678	679	680	681	682	683	684
685	686	687	688	689	690	691	692
693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708
709	710	711	712	713	714	715	716
717	718	719	720	721	722	723	724
725	726	727	728	729	730	731	732
733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748
749	750	751	752	753	754	755	756
757	758	759	760	761	762	763	764
765	766	767	768	769	770	771	772
773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788
789	790	791	792	793	794	795	796
797	798	799	800	801	802	803	804
805	806	807	808	809	810	811	812
813	814	815	816	817	818	819	820
821	822	823	824	825	826	827	828
829	830	831	832	833	834	835	836
837	838	839	840	841	842	843	844
845	846	847	848	849	850	851	852
853	854	855	856	857	858	859	860
861	862	863	864	865	866	867	868
869	870	871	872	873	874	875	876
877	878	879	880	881	882	883	884
885	886	887	888	889	890	891	892
893	894	895	896	897	898	899	900
901	902	903	904	905	906	907	908
909	910	911	912	913	914	915	916
917	918	919	920	921	922	923	924
925	926	927	928	929	930	931	932
933	934	935	936	937	938	939	940
941	942	943	944	945	946	947	948
949	950	951	952	953	954	955	956
957	958	959	960	961	962	963	964
965	966	967	968	969	970	971	972
973	974	975	976	977	978	979	980
981	982	983	984	985	986	987	988
989	990	991	992	993	994	995	996
997	998	999	1000	1001	1002	1003	1004
1005	1006	1007	1008	1009	1010	1011	1012
1013	1014	1015	1016	1017	1018	1019	1020
1021	1022	1023	1024	1025	1026	1027	1028
1029	1030	1031	1032	1033	1034	1035	1036
1037	1038	1039	1040	1041	1042	1043	1044
1045	1046	1047	1048	1049	1050	1051	1052
1053	1054	1055	1056	1057	1058	1059	1060
1061	1062	1063	1064	1065	1066	1067	1068
1069	1070	1071	1072	1073	1074	1075	1076
1077	1078	1079	1080	1081	1082	1083	1084
1085	1086	1087	1088	1089	1090	1091	1092
1093	1094	1095	1096	1097	1098	1099	1100
1101	1102	1103	1104	1105	1106	1107	1108
1109	1110	1111	1112	1113	1114	1115	1116
1117	1118	1119	1120	1121	1122	1123	1124
1125	1126	1127	1128	1129	1130	1131	1132
1133	1134	1135	1136	1137	1138	1139	1140
1141	1142	1143	1144	1145	1146	1147	1148
1149	1150	1151	1152	1153	1154	1155	1156
1157	1158	1159	1160	1161	1162	1163	1164
1165	1166	1167	1168	1169	1170	1171	1172
1173	1174	1175	1176	1177	1178	1179	1180
1181	1182	1183	1184	1185	1186	1187	1188
1189	1190	1191	1192	1193	1194	1195	1196
1197	1198	1199	1200	1201	1202	1203	1204
1205	1206	1207	1208	1209	1210	1211	1212
1213	1214	1215	1216	1217	1218	1219	1220
1221	1222	1223	1224	1225	1226	1227	1228
1229	1230	1231	1232	1233	1234	1235	1236
1237	1238	1239	1240	1241	1242	1243	1244
1245	1246	1247	1248	1249	1250	1251	1252
1253	1254	1255	1256	1257	1258	1259	1260
1261	1262	1263	1264	1265	1266	1267	1268
1269	1270	1271	1272	1273	1274	1275	1276
1277	1278	1279	1280	1281	1282	1283	1284
1285	1286	1287	1288	1289	1290	1291	1292
1293	1294	1295	1296	1297	1298	1299	1300
1301	1302	1303	1304	1305	1306	1307	1308
1309	1310	1311	1312	1313	1314	1315	1316
1317	1318	1319	1320	1321	1322	1323	1324
1325	1326	1327	1328	1329	1330	1331	1332
1333	1334	1335	1336	1337	1338	1339	1340
1341	1342	1343	1344	1345	1346	1347	1348
1349	1350	1351	1352	1353	1354	1355	1356
1357	1358	1359	1360	1361	1362	1363	1364
1365	1366	1367	1368	1369	1370	1371	1372
1373	1374	1375	1376	1377	1378	1379	1380
1381	1382	1383	1384	1385	1386	1387	1388
1389	1390	1391	1392	1393	1394	1395	1396
1397	1398	1399	1400	1401	1402	1403	1404
1405	1406	1407	1408	1409	1410	1411	1412
1413	1414	1415	1416	1417	1418	1419	1420
1421	1422	1423	1424	1425	1426	1427	1428
1429	1430	1431	1432	1433	1434	1435	1436
1437	1438	1439	1440	1441	1442	1443	1444
1445	1446	1447	1448	1449	1450	1451	1452
1453	1454	1455	1456	1457	1458	1459	1460
1461	1462	1463	1464	1465	1466	1467	1468
1469	1470	1471	1472	1473	1474	1475	1476
1477	1478	1479	1480	1481	1482	1483	1484
1485	1486	1487	1488	1489	1490	1491	1492
1493	1494	1495	1496	1497	1498	1499	1500
1501	1502	1503	1504	1505	1506	1507	1508
1509	1510	1511	1512	1513	1514	1515	1516
1517	1518	1519	1520	1521	1522	1523	1524
1525	1526	1527	1528	1529	1530	1531	1532
1533	1534	1535	1536	1537	1538	1539	1540
1541	1542	1543	1544	1545	1546	1547	1548
1549	1550	1551	1552	1553	1554	1555	1556
1557	1558	1559	1560	1561	1562	1563	1564
1565	1566	1567	1568	1569	1570	1571	1572
1573	1574	1575	1576	1577	1578	1579	1580
1581	1582	1583	1584	1585	1586	1587	1588
1589	1590	1591	1592	1593	1594	1595	1596

FIG. 4

HUNDRETH DEGREE CODE	CAM NOS.
231	232 233 234
LINE CONDUCTOR NOS.	
236	237 238 239

REC.DISPLAY UNIT LAMP NUMBER

05-14 25-34 45-54 95-04 15-24 35-44

65-74 85-94 ZONES 55-64 & 75-84 ZONES

4 5 6 7 8 9 5 4 5 6 7 8 9 5

FIG. 6

DEGREE CODE

CAM NOS.
211 212 213 214 215
LINE CONDUCTOR NOS.
226 227 228 229 230

DEGREE CAM
SET WITH
1/2° LEAD WHEN
VERNIER IS
ON ZERO

DEGREE
NUMBER
IN EACH
20° ZONE

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

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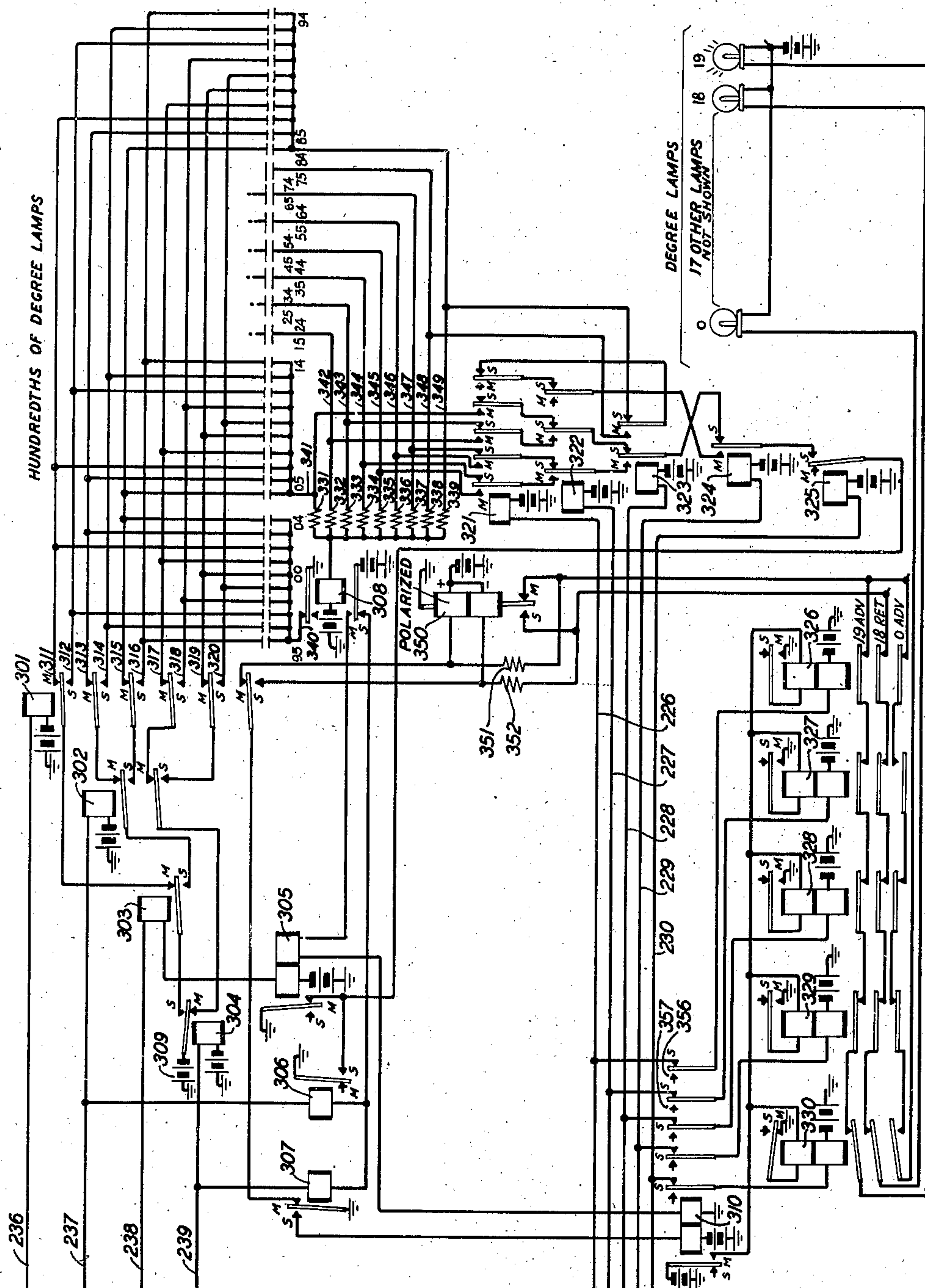
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DATA TRANSMISSION SYSTEM

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FIG. 3



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2,406,384

DATA TRANSMISSION SYSTEM

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Application November 5, 1942, Serial No. 464,564

5 Claims. (Cl. 177—351)

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This invention pertains to a system for instantaneously and continuously transmitting electrical impulses corresponding to a multidigit number from a first station to a second station.

The multidigit number may correspond to data readings at one station. The multidigit number may also designate a called subscriber's station in a switching system such as a communication system, for instance. The multidigit number may represent gradations of shade in a picture. In fact, the multidigit number may represent a very wide variety of things and conditions dependent upon the system where the invention herein is applied.

An object of this invention is the improvement of systems for transmitting data such as data represented by plural digit numbers from a first station to a second station.

Another object of the invention herein is the instantaneous transmission of electrical impulses corresponding to multidigit numbers which may, for instance, represent observed data from a first station to a second station.

A further object of this invention is the reduction in the number of channels required to transmit electrical impulses corresponding to multidigit numbers instantaneously from a first station to a second station.

A feature of this invention is the dividing of multidigit numbers representing data to be transmitted between stations into a plurality of subgroups of digits, the number of digits in each subgroup and the number of subgroups being chosen in such manner as to minimize the number of channels required for the instantaneous transmission of impulse in accordance with a permutation code to identify the multidigit number.

A further feature of this invention is the separation of a multidigit number into a plurality of subgroups of digits, the assigning of a separate permutation code to each subgroup and the assigning of a separate channel comprising a number of separate conducting elements corresponding to the number of elements in each permutation code for each channel so as to permit the transmission of electrical impulses corresponding to the multidigit number instantaneously between stations.

Another feature of this invention is a channel comprising five conducting elements for the transmission at different times of permutation codes defining a single digit number and employing only four of the five conducting elements and at other times of codes defining a two-

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digit number and requiring the employment of all five conducting elements so as to separately control apparatus individual to the single digit number and apparatus individual to the two-digit number.

Another feature of this invention is the disabling of the apparatus controlled in response to the signal elements defining the single digit number when signal impulses intended for the control of apparatus responsive to the two-digit number are transmitted and vice versa. These and other features of the invention will become apparent from the following detailed description when read with reference to the associated drawings in which:

Fig. 1 represents a drawing in schematic form showing two observing stations which are assumed to be located at points where observations are made and translated into data to be transmitted over direct current telegraph circuits connecting each observation circuit with a central station;

Fig. 2 shows the apparatus and wiring at a single observing station used in observing data at the observing station and transmitting electrical impulses corresponding to the data to the central station;

Fig. 3 shows one set of apparatus at the central station which is required to decode and record the data transmitted from one observing station;

Figs. 4, 5 and 6 are code charts used in explaining the operation of the apparatus per Fig. 2 and Fig. 3.

General

In one of its applications, the invention herein may be used in a data transmission system for observing data at one point and instantaneously translating the data into electrical impulses which are instantly transmitted to a central station. Such systems may be used, for instance, in determining the range and angular position of a target. In one system of range finding, two observing stations are located at the extremities of a base line of known length. The target is sighted through a rotatable telescope rigidly secured to a rotatable ring, the position of which with respect to a fixed point is indicated on a scale in terms of degrees and hundredths of a degree. A reference line such as a north-south line and having a fixed angular relation to the base line at each observing station, fixes the position of the fixed point at zero. The angular displacement of the telescope when directed at

the target establishes the line of direction of the target with respect to the base line. The intersection of the lines of sight at the two observing stations fixes the position of the target.

In the invention herein, it is possible to transmit instantaneously and continuously from each observing station to the central station electrical impulses corresponding to any number from 0 to 2000 to represent any one of two thousand positions within a 20-degree angle. In this system, the circle at the center of which each observing telescope is fixed is divided into eighteen equal segments, each consisting of twenty degrees. When the telescope is directed at a target, the particular 20-degree zone within which the target is located will first be determined by the attendant visually and the number of particular 20-degrees zone will be transmitted to the central station over some complementary facility, such as a telephone circuit or a separate telegraph circuit. The particular degree and hundredths of a degree positions within each 20-degree segment, as determined by the line of sight of the telescope directed at the target, will be automatically translated into electrical impulses which are transmitted instantaneously to the central station where the impulses are decoded and the data indicated.

In this system, it is to be understood, as mentioned above, that one observing station and one set of equipment such as Fig. 2 will be located at each end of the base line. Two sets of equipment such as Fig. 3 will be located at the central station. The equipment at each observing station is identical. The equipment required for decoding and recording the impulses received from each observing station is identical. In the description to follow, the manner in which one set of observing equipment at one end of a base line functions and the manner in which one set of decoding and recording equipment at the central stations functions will be described. It is to be understood that the equipment at the second observing station and the corresponding decoding and recording equipment at the central station functions in the identical manner.

Refer now to Fig. 2. A telescope 201 is directed at the target. The particular 20-degree zone within which the line is located is made known to the attendant at the central station by means of a separate telephone or telegraph circuit. Once the target is sighted the telescope 201 is continuously directed at the target by the observer who will turn the vernier crank 202 in such manner as to maintain the line of sight through the telescope on the target. As the vernier crank is turned, the telescope is rotated by means of worm 203 which engages with worm gear 204 on a disc 205 to which the telescope 201 is rigidly secured by means of spindle 206. One complete rotation of the vernier shaft turns the telescope through one degree through gearing having a ratio of 360 to 1. As the telescope is rotated the radial horizontal arm 207 is rotated with it. The outer end of radial arm 207 forms a bearing and support for vertical shaft 208. A pinion 209 is secured to shaft 208 in position to engage ring gear 210 which is rigidly secured to a tripod (not shown) used to support the observing instrument and its associated mechanisms.

As the vernier crank is turned, the disc or platform 205 supporting the telescope 201 is rotated. Radial arm 207 is rotated revolving the vertical shaft 208. As the shaft 208 revolves, pinion 209 engages ring gear 210. Thus shaft

208, while revolving about spindle 206 as a center, rotates also about its own center. The ratio of the gear 210 to gear 209 is such that shaft 208 rotates about its own axis once while revolving through twenty degrees about the vertical axis of the telescope. Secured to shaft 208 are 5-degree cams 211 to 215, inclusive. The five cams control five followers 216 to 220, inclusive, which when actuated by their respective cams supply ground through individual contacts. The 5-degree cams 211 to 215 are arranged to close their individual contacts in accordance with a permutation code so as to transmit twenty different combinations of impulses for each rotation of shaft 208 to identify each of the 20-degree divisions within each of the eighteen sectors into which the circle is assumed to be divided. Each of cams 211 to 215 therefore is divided into twenty equal segments arranged to either open or close its respective contact to provide twenty different combinations for each revolution of shaft 208 to define each of the twenty degrees as indicated in Fig. 6. Mounted on the horizontal crankshaft are five cams numbered 221 to 225, inclusive. Four of these cams 221 to 224, inclusive, are used in transmitting impulses corresponding to the tenths of a degree within each degree. The fifth cam, cam 225, is used in operating a switch the primary function of which is to keep the degree information separate from the tenths of a degree information. The manner in which this functions will be explained in detail below. At this point, however, attention is called to the fact that the same five conductors 226 to 230, inclusive, which, taken together, constitute a channel arranged to transmit instantaneously impulses defining any of thirty-two numbers is used at separate times to transmit impulses defining any of the twenty degrees within a particular sector and any of the tenths of a degree within each degree. It is pointed out that in order to transmit twenty different sets of impulses corresponding to twenty different degrees and ten different sets of impulses corresponding to the tenths of a degree within each degree, if it is to be done in each instance instantaneously, a channel capable of providing for the transmission of thirty different sets of impulses must be provided. The five-conductor channel comprising conductors 226 to 230, inclusive, can transmit instantaneously any one of 25 or thirty-two different sets of impulses to define thirty-two numbers. Only thirty of these will be employed, however. Twenty of these sets of impulses will define twenty equal steps in the rotation of cams 211 to 215, inclusive, through each 20-degree zone. Ten of the characters will define ten equal divisions in one rotation of vernier crankshaft 202. Crank 202 in one complete rotation turns telescope 201 through one degree. The ten divisions are equal, each defining a tenth of a degree.

A separate channel is devoted to the transmission of impulses defining the ten one-hundredths of a degree in each tenth of a degree. The channel comprises four conductors 236 to 239, inclusive. By means of the four conductors, it would be possible to transmit instantaneously any of sixteen different sets of impulses defining sixteen numbers or characters. Only ten of these are required to transmit impulses defining ten different hundredths of a degree. As crankshaft 202 rotates through one-tenth of a revolution, ten different sets of impulses, each defining a different hundredth of a degree, are trans-

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mitted over conductors 236 to 239, inclusive, through the operation of cams 231 to 234, inclusive, each of which actuates its individual follower to close an individual contact to ground in accordance with the assigned code.

Attention is particularly called to the fact that one complete revolution of vernier crank 202 rotates telescope 201 through one degree. It would appear desirable, therefore, in coupling a shaft through gearing to the vernier shaft for controlling the transmission of impulses to define each of ten-hundredths of a degree to provide gearing having a ratio of ten to one so that the hundredths of a degree shaft would make ten revolutions for each revolution of the vernier shaft. For reasons which will be made apparent below, the shaft on which the hundredths of degree cams are mounted is coupled to the vernier shaft through gearing having a ratio of but five to one so that the hundredths of a degree shaft revolves but five instead of ten times for each revolution of the vernier shaft. For each revolution of the hundredths of a degree shaft, therefore, the vernier shaft rotates through twenty one-hundredths of a degree. During this interval, twenty sets of impulses, each defining a different one-hundredth of a degree, are transmitted over conductors 236 to 239, inclusive. While the hundredths of a degree shaft 240 rotates through the first half of a revolution, which corresponds to ten one-hundredths of a degree, ten different sets of impulses, each defining ten different one-hundredths of a degree, are transmitted over conductors 236 to 239, inclusive. While shaft 240 turns through the second half of a single rotation, ten more sets of impulses each defining ten different hundredths of a degree are transmitted, making a total of twenty-hundredths of a degree. Each of cams 231 to 234 is divided into twenty equal segments. Each segment will either raise its respective cam follower to close its contact or permit it to remain in the lowered position. By means of the four conductors 236 to 239 and the four sets of cams 231 to 234 it would be possible to transmit instantaneously any one of 2^4 or sixteen combinations of signal impulses resulting from the open or closed conditions of each of the four contacts. It is necessary to make use of only ten of these sixteen possible combinations to define each of ten-hundredths of a degree. As shaft 240 turns through the first half of each revolution its four cams 231 to 234 set up ten different combinations of closed and open contacts to define ten different hundredths of a degree as indicated in the code chart per Fig. 4 in the top ten lines of the box. As indicated in the first line for the first position, all contacts are open since none of the four rectangles in the first line is cross-hatched. For the second position, when shaft 240 has turned through one-twentieth of a revolution contact 242 closes. When shaft 240 turns through another twentieth revolution, contact 243 also closes. As shaft 240 turns through each successive twentieth of a revolution, contacts 241 to 244 close or open as indicated in Fig. 4. It is particularly pointed out that only ten distinctive code combinations are employed. Each of the ten combinations which is employed is used twice to define each of twenty-hundredths of a degree. It is further pointed out that when the combinations are repeated they are repeated in reverse order. That is to say, the cam cuttings in the eleventh position instead of being the same as in the first position are the

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same as in the tenth position. This may be seen from reference to the tenth and eleventh lines from the top in Fig. 4. The cam cuttings in the twelfth position instead of being the same as in the second position are the same as in the ninth, etc. The cuttings of the first position are not repeated until the twentieth position is reached. The reason for this will be made apparent below.

Transmission of hundredths of a degree information

The manner in which the hundredths of a degree information is transmitted from the observing station to the central station will first be described.

When cam 231 raises its follower, a circuit is closed from ground through contact 241, conductor 236 and the winding of relay 301 to battery operating the relay 301 to engage its M contact. When cam 232 raises its follower a circuit is closed from ground through contact 242, conductor 237 and the winding of relay 302 to battery, operating the armature of relay 302 to engage its M contact. The winding of relay 306 is connected in parallel with the winding of relay 302. Its operation will be described below. When cam 233 raises its follower a circuit is established from ground through contact 243, conductor 238, winding of relay 303 and the left-hand winding of relay 305 to battery, operating the armature of relays 303 and 305 to engage their respective M contacts. Relay 305 is not directly involved in the transmission of hundredths of a degree information and its function will be described more fully later. When cam 234 raises its follower, a circuit is established from ground through contact 244, conductor 239 and the winding of relay 304 to battery, operating the armature of relay 304 to engage its M contact. A parallel circuit is also established extending through the winding of relay 307 to the S contact of relay 308, the function of which will be explained below.

Relays 301, 302, 303 and 304 control the selective connection of battery 309 through a fan circuit extending through the armatures and contacts of relays 301, 302, 303 and 304 to ten conductors, numbered 311 to 320, inclusive. Each of conductors 311 to 320 has ten parallel branches, each extending to the top terminal of a lamp. The lamps are arranged in ten banks of ten. Each of the ten conductors has one branch extending into one lamp in each group of ten lamps. As thus arranged, as cams 231 to 234 actuate their followers in accordance with the ten codes in the top ten lines of Fig. 4, relays 301 to 304 will be operated or released correspondingly to connect battery 309 in turn to the ten different conductors 311 to 320 and through each of the ten different conductors simultaneously to the top terminal of each of ten lamps connected in parallel to each conductor. One lamp in each bank of ten lamps will thus have battery connected to its top terminal for each of the ten codes during the first half revolution of shaft 240. The same lamp in each bank of ten lamps will also have battery connected to its top terminal as shaft 240 turns through the second half of its revolution and actuates cams 241 to 244 in accordance with the same code in reverse order. It is particularly pointed out that battery is supplied to the top terminals of each of the hundred lamps twice during one complete revolution of shaft 240 and that if a steady ground were connected to the opposite terminal of each lamp, one lamp in each bank of ten would light simultaneously. Ten

lamps, one in each bank of ten, would first light. Then as the code changed ten other lamps, one in each bank of ten, would light until each of the ten lamps in each group of ten had lighted as shaft 240 rotated through one-half revolution. Then the operation would be repeated, so that if a direct ground were connected to the bottom terminals of all of the hundredths of a degree lamps, there would be two hundred lamp lighting operations as shaft 240 turned through one revolution representing twenty-hundredths of a degree. Only twenty lamps are in fact lighted, one lamp at a time, to define twenty one-hundredths of a degree change for each revolution of shaft 240. This is performed by connecting ground selectively to the proper group of tens lamps in each bank, under control of cams 221 to 224, which define the tenths of a degree. The manner in which this is performed will be explained below.

The chain circuits through the contacts of relay 301 to 304 corresponding to various codes per Fig. 4 will now be traced. It is assumed that the armature of relays 301 to 304 are actuated to their respective M contacts when cam contacts 241 to 244 are closed and that the contacts are closed by raised surfaces on cams 231 to 234 in the cross-hatched positions in Fig. 4. It is assumed that the armatures of relays 301 to 304 are open and that the contacts are open by depressed surfaces on cams 231 to 234 where positions are not cross-hatched in Fig. 4.

In Fig. 4 four vertical rows from left to right represent the condition of cam contacts 241 to 244, respectively, whether open or closed. There are twenty horizontal rows in Fig. 4 corresponding to the twenty equal segments into which the peripheries of cams 231 to 234 are divided. Instead of being numbered from 0 to 9 and then repeating from 0 to 9 the horizontal rows are numbered 5, 6, 7, 8, 9, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 1, 2, 3, 4. The reason for this, as will become more apparent below, is that the code for the degrees, controlled by contacts 216 to 220 is transmitted from the observation station during the interval while the hundredths cams are in the zero region and it lessens the danger of interference if no changes in the ground connections, to the ten banks of ten lamps, under control of cams 221 to 224 are made in the zero region. Therefore the hundred lamps are separated into groups of ten, as indicated in Fig. 3, between 04 and 05, 14 and 15, etc., to 94 and 95.

As indicated in Fig. 3, the first group of ten lamps are numbered from 95 to 04. It will be shown that ground is connected to this bank of ten lamps when cams 221 to 224 are in the position indicated in Fig. 2. That is to say, when the contacts associated with cams 221 to 224 are all open, the tenth degree relays 321 to 324 controlled by these cams are in such condition that ground is connected to lamp bank numbered 95 to 04. Therefore during the first half of the first revolution of shaft 240, ground is connected to lamp bank 95 to 04. During the second half of the revolution of cam shaft 240, ground will be connected to the bank of lamps numbered 05 to 14. During the first half of the second revolution of shaft 240 ground will be connected to lamps 15 to 24. During the second half of the second revolution, ground will be connected to lamps 25 to 34, etc. Relays 321 to 325 will be operated under control of cams 221 to 224 in accordance with the code indicated in Fig. 5 to effect these changes. At the left of Fig. 4 therefore the numbers 95-04

appear opposite the top ten lines numbered 5, 6, 7, 8, 9, 0, 1, 2, 3, 4 indicating that lamps 95, 96, 97, 98, 99, 100, 101, 102, 103 and 104 are controlled in sequence by cam cuttings, arranged in accordance with the pattern in the first ten positions in sequence on cams 231 to 234. Numbers 15-24, 35-44, 55-64 and 75 to 84 opposite the same top ten lines indicate that lamps so numbered are also so controlled. Numbers 05-14, 25-34, 45-54, 65-74 and 85-94 opposite the bottom ten horizontal lines in Fig. 4 indicate that lamps so numbered are controlled by cam cuttings arranged in accordance with the pattern in the second ten positions on cams 231 to 234.

Refer now to the code indicated by the top line of Fig. 4. No raised surfaces are indicated for any cam. Relays 301 to 304 are all released. For this condition all of their armatures engage their respective S contacts. A circuit may therefore be traced from battery 309 through the S contact of relay 304, S contact of relay 303, IS contact of relay 302 and 3S contact of relay 301 to conductor 316 which connects to lamp 95.

The next code requires the operation of relay 302 and the release of 301, 303 and 304. The circuit may be traced from battery 309 through the S contact of relay 304, S contact of relay 303, IM contact of relay 302 and the 2S contact of relay 301 to conductor 314. This connects to lamp 96.

The code shown in the third line of Fig. 4 calls for the operation of relays 302 and 303 and the release of relays 301 and 304. A circuit may be traced from battery 309 through the S contact of relay 304, M contact of relay 303, and the IS contact of relay 301 to conductor 312 which connects to lamp 97. If the circuits corresponding to the remainder of the codes indicated in the next seven lines in sequence are traced they will be seen to connect battery 309 to the top terminal of lamps 98 to 04 in sequence.

During the interval while shaft 240 is rotating through the first half of its first revolution it will be shown below that a common ground is connected, as a result of the operation of the tenth degree cams, to lamp bank 95 to 04 in parallel, so that each of these lamps lights in sequence.

After completing the first half of the first revolution, when shaft 240 rotates into the eleventh position of its twenty positions for the first cam setting for the second half of its rotation, reference to Fig. 4 indicates that there is no change in the settings of the cams from the settings for the tenth position. In the tenth position contact 241 only is closed. The other contacts are open. Relay 301 only is operated in the tenth position. The circuit for this condition may be traced from battery 309 through contact S of relay 304, contact S of relay 303, contact IS of relay 302 and contact 3M of relay 301 to conductor 315. Conductor 315 connects to lamp 04 in the first bank of ten lamps. The setting of the hundredth degree cams, as indicated in Fig. 4, does not change between the tenth and eleventh position of the twenty positions on cams 231 to 234. Battery will therefore remain connected to conductor 315 for each transition between the tenth and eleventh settings of the cams as the cam settings are the same and do not change in any way. As a result of this, it is necessary to change the ground connections only on changes from 04 to 05, 14 to 15, 24 to 25, 34 to 35, 44 to 45, 54 to 55, 64 to 65, 74 to 75, 84 to 85, and 94 to 95.

The bottom line in Fig. 4 shows that the code for lamps 14, 34, 54, 74 and 94 requires that all

four of relays 301 to 304 be released. If the path for this condition is traced it may be seen to extend from battery 309 through contact 304S, contact 303S, contact 1S of relay 302 and contact 3S of relay 301 to conductor 316. The top line in Fig. 4 shows that the code for lamps 15, 35, 55, 75 and 95 and therefore the setting of the relays and the connection of battery to the conductor is the same as that for lamps 14, 34, 54, 74 and 94. Conductor 316 is shown connected to lamps 14 and 15, 34 and 35, 54 and 55, 74 and 75, and 94 and 95. Reference to Fig. 3 shows that lamps 14, 34, 54, 74 and 94 are each the last lamps in various banks of ten, while lamps 15, 35, 55, 75 and 95 are each the first lamps in corresponding succeeding banks of ten. No change therefore is required in the settings of the relays and in the chain circuits from battery to the top terminal of each of these lamps for transitions between them. The transition requires a change in the ground connection only between the common conductors connected in multiple to the bottom terminals of the particular groups of ten lamps affected by the transition.

Operation of circuit for indicating transition between tenths of a degree

Transitions between tenths of a degree effect changes in the settings of contacts individual to cams 221 to 224 in accordance with Fig. 5. The table at the left of Fig. 4 indicates the tenth degree zones defined by cam settings in the corresponding ten lines of Fig. 5. Instead of dividing the tenth degree zones between 99 and 100, 9 and 10, etc. the zones are divided between 94 and 95, 04 and 05, etc. as indicated in the table to correspond with the lamp groupings described above.

As cam contacts 221 to 224 are closed and opened, in accordance with the codes per Fig. 5, relays 321 to 325 are operated and released from ground through the cam contacts, conductors 226 to 229, respectively and the windings of the relays 321 to 325 to battery.

Attention is called to the fact that conductors 226 to 229 are only four conducting elements of a channel consisting of five conducting elements. The fifth conducting element, conductor 230, is not employed in transmitting any of the codes for the tenths of a degree. Reference to the right-hand vertical column in Fig. 5 discloses that the fifth conductor, conductor 230, remains in the open condition for each of the codes assigned to the tenths of a degree. Codes requiring the closing of conductor 230 are assigned only to degrees. This may be seen in the right-hand vertical column of Fig. 6.

A number of the circuits established by the operation of the tenth degree cams will now be traced.

The top line in Fig. 5 indicates that all of cam contacts 221 to 224 are open for the tenth degree zone starting at each ninety-fifth hundredth of a degree and ending at each fourth hundredths of a degree or 95-04 as indicated in Fig. 5. Whenever tenth of a degree codes are transmitted conductor 230 is open as indicated in the right-hand column of Fig. 5. Why it is open will become more apparent below. For this condition therefore relays 321 to 325 are released. When all of these relays are released, the path leading from the parallel branches connected to the M contact of relay 305 and the S contact of relay 306 and extending through contact 325S, contact 324S, contact 1S of relay 323 and contact 2S of relay 322 is open at the 4S contact of relay 321. So

no matter what the condition of relay 305 or 306, relay 308 will be released for this condition. Reference to relay 308 shows that battery is permanently connected to the left-hand terminal of its winding. To operate the relay ground must be supplied through the chain circuit to the right-hand terminal of the winding. When relay 308 is released, ground is supplied through its upper armature and S contact through conductor 340 to lamps 95-04 in parallel.

While ground is connected in parallel to lamps 95-04, each of these lamps will be lighted in sequence as the vernier is turned through corresponding positions for each degree.

Reference to the second line of Fig. 5 shows that for the second tenth-degree zone, that is, for the ten of a degree beginning at five-hundredths of a degree and ending at fourteen-hundredths of a degree, or 05-14, cam 221 operates relay 321. Relays 322, 323, 324 and 325 are released. Relay 306 is released during the transition from 04 to 05 because, as shown in lines 10 and 11 of Fig. 4 the periphery of cam 232 is depressed during this interval. Therefore ground is connected through the S contact of relay 306, S contact of relay 325, S contact of relay 324, 1S contact of relay 323, 2S contact of relay 322 and the 4M contact of relay 321, which is the only operated relay in the chain, to a parallel circuit. One branch of the parallel circuit is connected in parallel through conductor 341 to the bottom terminals of lamps 05-14. The other branch is connected through resistance 331 and the winding of relay 308 to battery, operating relay 308. When battery is connected to the bottom terminal of lamps 05-14 each of these lamps is lighted in sequence as the vernier rotates through corresponding positions. The operation of relay 308 disconnects ground from its top S contact and conductor 340 which prevents the lighting of any of lamps 95-04 while the vernier is rotating from 05-14. The operation of relay 308 also established a circuit from battery through bottom contact 308M, right-hand winding of relay 305 and the right-hand winding of relay 310, operating the armatures of relays 305 and 310 to engage their respective M contacts.

It is particularly pointed out that relay 308 is released only during the interval while the vernier is in the region between 95 and 04. For each other tenths degree combination relay 308 is operated from ground supplied from relay 305 or 306 through an individual path through the fan circuit extending through the contacts of relays 321 to 325, inclusive and some one of the resistances 331 to 339, inclusive to the right-hand terminal of relay 308. A corresponding bank of ten lamps will be lighted through some one of conductors 341 to 349. For instance, for the tenth degree zone beginning at 15 hundredths and ending at 24 hundredths in each degree as indicated in Fig. 5, the contacts of cams 221 and 222 will be closed and the contacts of cams 223, 224 will be open. A circuit may therefore be traced from ground through contact 305M, contact 325S, contact 324S, contact 1S of relay 323, contact 2M of relay 322 and contact 3M of relay 321 which connects in parallel through resistance 332 to the right-hand terminal of relay 308 and through conductor 342 to lamp banks 15 to 24. For the tenth degree zone beginning at vernier position 25 and ending at vernier position 34, as indicated in line 4 of Fig. 4, relay 322 is the only chain relay operated. The circuit will therefore extend from ground through contact 305M, contact 325S, contact 324S, contact 1S of relay 323, con-

tact 2M of relay 322 and contact 3S of relay 321 to resistance 333 and conductor 343 in parallel. Relay 303 remains operated and the bottom terminals of lamps in the bank 25-34 are supplied with ground. For vernier positions 35-44, 45-54, 55-64, 65-74, 75-84 and 85-94, if relays 321-325 are assumed to be operated where a position in a corresponding line in Fig. 5 is cross-hatched and released where a position is blank, circuits may be traced from ground through contact 305M and through an individual path through contacts of relays 321 to 325 for each relay group setting indicated by the particular line in Fig. 5 to a single group of ten lamps correspondingly numbered. Relay 308 will be maintained operated simultaneously from ground supplied through resistances 333 to 339.

Only one bank of ten lamps will have battery supplied to its bottom terminals at any one time. Relay 308 is released only while the vernier is in the teeth of a degree position between 95 hundredths and 04 hundredths. Therefore ground will be supplied to lamp bank 95-04 only during this interval. During the interval while relay 308 is operated while the vernier is in the other 90 hundredths of a degree positions, ground can be connected to only one bank of ten lamps for each of the settings indicated in the nine bottom groups of codes of Fig. 5. Reference to the various possible circuits through relays 321 to 325 will disclose that it is not possible to establish more than one closed path through their contacts simultaneously for any of the operate and release conditions of relays 321 and 325 indicated in any of the code conditions of Fig. 5.

The cooperation of the apparatus governing the selection of each of the lamps by the hundredths of a degree mechanism and the tenth of a degree mechanism therefore will result in the lighting of one lamp only for each one-hundredth setting of the vernier.

Transmission of degree information

The manner in which the mechanism functions to transmit degree information will now be described.

It has been explained that as shaft 208 revolves through twenty degrees about spindle 206, it rotates once on its own axis, turning each of cams 211 to 215 through a single rotation. During this single rotation contacts 216 to 220 are set in twenty different combinations to transmit twenty different combinations of impulses to define twenty different degrees as shown in Fig. 6.

Since the same channel consisting of individual conducting elements 226 to 230 is used to transmit both tenths of a degree information as well as degree information, provision is made, in an important feature of this invention, to prevent interference in operation between the mechanism employed to transmit and record this information. A separate set of recording relays 326 to 330 is provided to record the degree information. Conductors 226 to 230 inclusive are extended through the bottom windings of relays 326 to 330, respectively. Relays 326 to 330 respond to the code of the degree information. The degree impulses are transmitted while the vernier is in the portion of the 95 to 04 tenths zone between 98 and 01. Relays 321 to 325 for the tenths of degrees respond to the degree codes and change the circuits through their contacts but in no case is a circuit continuous from ground through the contacts of relays 321 to 325 to any of the banks of lamps or to the winding of relay

308, which relay remains released. No lamp in any bank can therefore be affected by the transmission of the degree information.

In the description above it was explained that all of the contacts of cams 221 to 224 are open when the code for the tenths of a degree zone, starting at 95 hundredths and ending at 04 hundredths, is transmitted. This is indicated in the top line of Fig. 5. It was also explained that during this interval relay 308 remained released and that ground was supplied to the bottom terminal of lamps 95 to 04 through the top S contact of relay 308 instead of from the M contact of relay 305 or the S contact of relay 306. It is not necessary therefore to supply ground from relays 305 or 306 to any of the lamps or to the right-hand terminal of relay 308 for the tenths zone beginning at 95 and ending at 04. The ground from relays 305 and 306 is therefore disconnected from the chain circuit for a number of the positions of the vernier in the zero hundredths region while the degree code information is transmitted. Therefore, no matter whether or not relays 321 to 325 are operated or released in response to the degree codes, the lamp banks corresponding to the hundredths of a degree are not affected in any way.

Normally switch 245 is open. Switch 245 has five separate contacts. It is under control of cam 225, mounted on vernier shaft 202. Cam 225 operates switch 245 to close the five circuits from cam contacts 216 to 220 through the five armatures of switch 245, conductors 226 to 230 and the windings of relays 326 to 330 and 321 to 325 in parallel to battery, while the vernier is in position 96.5 to 03.5. Only during this interval corresponding to seven one-hundredths of a degree can degree codes be transmitted. The degree cams actually set their respective contacts, which thereafter remain set for each degree code, while the vernier is moving between 45 and 50. This is approximately one-half degree in advance of the position of the vernier at which the codes set up during the 45 to 50 interval are actually transmitted. The reason for this is to insure that the degree cams' contacts are actually at rest in their proper positions when they are connected to their respective conductors 226 to 230, to reduce the possibility for mutilation due to possible bouncing of the contacts, etc., when closed or opened, if they were closed and opened at about the time that they were connected to their conductors.

There is another protective feature in the invention designed to guard against mutilation during the closing and opening of the contacts of switch 245. In the two vernier positions in which the position of switch 245 actually changes the positions of its five contacts, namely at 96 and 03, whether to open or close the switch, depending upon the direction of rotation of the vernier on either increasing or decreasing azimuth, ground is disconnected from the fan circuit through relays 321 to 325 to the hundredths lamps. Reference to the second line from the top in Fig. 4 shows that at position 96 of the vernier, contact 242 only is operated by hundredths of a degree cam 232. This connects ground through conductor 237 to the top terminal of relay 306. Since relay 308 is released for the 95 to 04 tenths of a degree zone, battery is connected from bottom contact 308S to the bottom terminal of relay 306 operating relay 306 in this position. The armature of relay 306 is in engagement with its M contact so that no ground is connected through the fan circuit of relays 321 to 325 from relay 306

for this condition. Both windings of relay 305 are deenergized for this condition because battery is disconnected from the bottom M contact of relay 308 so that the right-hand winding of relay 305 is deenergized and contact 243 is open so that the left-hand winding of relay 305 is deenergized. The armature of relay 305 is on its S contact. No ground therefore can be connected to the fan circuit through relays 321 to 325 from relay 305 either. So ground is disconnected from the fan circuit through relays 321 to 325 for position 96 in each degree.

Reference to the ninth line from the top in Fig. 4 for the 03 position of the vernier indicates that the positions of cams 232 and 233 is unchanged from that for vernier position 96 described above. Relays 305 and 306 are in the same condition as described above and ground is disconnected from the fan circuit for this position also. As a result of this even though a perfect simultaneous closing or opening of all of the contacts of switch 245 in vernier positions 96 and 03 is not effected, the banks of the hundredth degree lamps will be unaffected as no ground is connected through the fan circuit of relays 321 to 325 for either of these vernier positions. The contacts will assume a proper final position, however, whether open or closed before the vernier has moved into the succeeding position.

To return now to a consideration of the operation of relays 326 to 330 which record the degree settings, these relays are normally in positions corresponding to the code last recorded by them. Relays which have been last operated by the code are locked operated. Relays 326 to 330 are neutral relays. Relay 310 functions to unlock those of them which have been locked in the operated position by the impulses of the previous code and to connect them to conductors 226 to 230 only while the vernier is in a few positions in the zero region. This will be fully explained below. The relays are set in accordance with the code for the new degree cam setting. Then relays 326 to 330 are disconnected from conductors 226 to 230 so that their settings will not be mutilated by the codes for tenths of a degree. Since relays 326 to 330 are neutral relays those of them which have been operated by the particular degree code must be locked in the operated position between the reception of degree codes. This is effected by a locking circuit through each of their top windings under control of relay 310.

It was shown above that relay 308 is operated for ninety of the one hundred vernier positions namely from positions 05 to 94. During this interval, as explained above, the armature of relay 308 remains in engagement with its M contact which establishes a circuit heretofore traced from battery through contact 308M and the right-hand windings of relays 305 and 310. Relay 310 remains operated over this path and its armature therefore remains in engagement with its M contact while the vernier is in any of the ninety positions from 05 to 94. As may be observed, there is a second winding on relay 310. The left-hand winding is under control of relay 307. The left-hand winding of relay 310 is energized while relay 307 is released. Relay 307 is under dual control. In order to energize relay 307, relay 308 must be released to connect battery to the bottom terminal of relay 307 and cam 234 must close contact 244 to connect ground to the top terminal of relay 307. Battery is connected to the bottom terminal of relay 307, as has been shown, while the vernier is in the ten positions from 95 to 04

only. Reference to the top ten code groups of Fig. 4 shows that during this interval cam 234 closes contact 244 in positions 98, 99, 00 and 01. Relay 307, therefore, is operated only while the vernier is in the four positions 98, 99, 00 and 01. Relay 310 is released and relays 326 to 330 are in condition to respond to degree codes therefore only while the vernier is in positions 98, 99, 00 and 01. During the other ninety-six positions of the vernier relay 307 is released and ground is connected through contact 307S and the left-hand winding of relay 310 operating relay 310. The operation of relay 310 for the ninety-six positions of the vernier from 02 to 97 opens the operating paths through each of relays 326 to 330. The operation of relay 310 also locks those of relays 326 to 330 which have been operated by the code impulses.

Relays 326 to 330 are operated or released in accordance with the degree codes. The top armature of any of these relays which is operated is actuated to engage its M contact. Relay 310 is fast in operating and operates before any one of relays 326 to 330 which has been operated can be released. This established a locking path from battery through contact 310M top windings of relays 326 to 330, armatures of relays 326 to 330 and to ground through the top M contact of any relay which has been operated, locking each operated relay. Relays which are not operated in accordance with the received code, of course, remain in their normal released positions. The paths from the degree cam contacts to conductors 226 to 230 remain open, due to the operation of cam 225 and the opening of switch 245, until the change in setting of the azimuth requires a change in setting of the degree relays. Relay 310 remains operated during this interval and the settings of relays 326 to 330 remain unchanged.

If the telescope 201 were not required to be rotated in more than one direction, such as clockwise, it would be necessary to provide only twenty individual degree lamp selecting circuits, one for each of the twenty degree lamps. One such selecting circuit would be established by the operation and release of relays 326 to 330 for each of the twenty codes indicated in Fig. 6. The telescope 201 must be rotatable in either the clockwise or counter-clockwise direction, however, to follow a target the movement of which is unrestricted.

Let it be assumed that the position of the telescope is in the neighborhood of 18.25 degrees and that the azimuth is increasing. As the vernier passes through 18.45 degrees to 18.50 degrees a new code is set up by cams 211 to 215. The code will be stored on the contacts and will not be transmitted to relays 326 to 330 for recording until the vernier is in position 18.98 degrees. Let it be assumed that, in response to these, the 19-degree lamp is lighted when the vernier crosses 19.00 degrees. If the azimuth continues to increase there is no difficulty. Suppose, however, that the telescope must be rotated in the opposite direction back into the 18-degree zone. Since the cam settings for the degree code will not again change until the azimuth is in the 18.50 degree to 18.45 degree zone, some provision must be made to record the change back into the 18-degree zone.

In order to do this two selecting circuits are established through the contacts of relays 326 to 330 for each of the twenty different degree codes shown in Fig. 6. Relays 326 to 330 are each equipped with forty sets of bottom contacts. Only three sets are actually shown. Two identi-

cal-chain circuits are established through the contacts of relays 326 to 330 for each of the twenty different codes. There is one chain circuit for increasing and another for decreasing vernier for each degree. Each such pair of chain circuits is connectable through a lamp to battery. There is but one lamp for each degree cam setting. The opposite ends of each chain circuit is connectable to ground through the opposed contacts and armatures of polar relay 350. The polar relay is controlled by the hundredths degree cams in such manner that when the vernier passes through position 19.00 degrees on increasing azimuth one of the chain circuits controlled by the code for nineteen degrees and designated the 19-degree advance chain will be connected to ground to light lamp 19. When the vernier passes through position 19.00 on decreasing azimuth the other of two chain circuits controlled by the code for nineteen degrees but designated 18-degree retrogress lamp will be energized to light lamp 18.

The manner in which the twenty pairs of chain circuits corresponding to twenty codes such as indicated in Fig. 6 may be established through forty sets of contacts of the five relays 326 to 330 should be obvious from reference to the three chain circuits which are shown by way of example. The circuit for 19-degree advance may be traced from battery through the filament of the 19-degree advance lamp through the front contact of relay 330 and through the break contacts of relays 329, 328, 327 and 326 in sequence, the settings of all of which relays correspond to the code for nineteen shown in the bottom line of Fig. 6, to the M contact of relay 350. The circuit for the 18-degree retrogress lamp may be traced from battery through the filament of the 18-degree retrogress lamp through the front contact of relay 330 and through the back contacts of relays 329, 328, 327 and 326 to the S contact of relay 350. Attention is called to the fact that the position of the relay contacts in the chain circuits through relays 326 to 330 is the same for both of these lamps. Both of these chain circuits were established by the same setting of the degree cams, namely the cam settings established when the azimuth passed between 18.45 degrees to 18.50 degrees and both correspond to the setting indicated "19" in the bottom line of Fig. 6.

Which of the two lamps 19 advance or 18 retrogress is lighted will depend upon the direction of the movement of the vernier and the operation of the hundredths of a degree cams in response thereto. This will now be explained in detail.

Relay 350 is under control of relays 301 and 307. In order to move the armature of relay 350 in either direction, ground must be supplied from relay 307. It has been shown above that relay 307 is operated for each degree in only four of the hundred positions of the vernier. These positions, it was shown were 98, 99, 00 and 01. The ground is supplied from relay 307 through its armature and M contact and through either contact 6M of relay 301, when relay 301 is operated, to battery through the top winding of relay 350, or through contact 6S of relay 301, when relay 301 is released, to battery through the bottom winding of relay 350. The position of relay 301 while the vernier is in positions 98, 99, 00 and 01 determines which of the windings of relay 350 is energized by the ground from relay 307. This in turn determines in which direction the armature of relay 350 will be actuated and which of the two lamp circuits set up by such degree code will be closed.

Relay 350 is provided with two locking circuits. One extends from battery through the top winding of relay 350, through resistance 351 to the M contact of relay 350. The other extends from battery through the bottom winding of relay 351, through resistance 352 to the S contact of relay 350. When the armature of relay 350 is on its M contact, current sufficient to hold the armature in engagement with the M contact flows through the top winding provided full current does not flow through the bottom winding. When the armature of relay 350 is on its S contact, current sufficient to hold the armature in engagement with its S contact flows through the bottom winding provided full current does not flow through the top winding. In ninety-six of the hundred vernier positions in each degree the armature of relay 350 will be held in engagement with either its S or its M contact by either of its locking windings. The contact on which the armature is held is the contact to which it was last actuated by relay 301 while the vernier was in the four vernier positions 98, 99, 00 and 01 and ground was supplied from the M contact of relay 307.

Let it be assumed that the armature of relay 350 is in engagement with its M contact and that it is locked to its M contact by current flowing from battery through the top winding of relay 350, through resistance 351 and the M contact of relay 350 through its armature to ground. Let it be assumed that telescope 201 is in position 18.30 degrees and that the azimuth is increasing. When the vernier moves through positions 18.45 degrees to 18.50 degrees the 19 code will be set up on contacts 216 to 220 by cams 211 to 215. Switch 245 is open so the degree code is not transmitted at this time. The code for the tenths and hundredths of a degree are transmitted continuously by the action of cams 221 to 224 and 231 to 234. When the vernier reaches position 18.95 degrees relay 308 releases. When the vernier reaches 18.965 degrees switch 245 closes. When the vernier reaches 18.98 degrees relay 307 operates. Relay 310 which has been locked is released. The particular relays of the degree coding relays 326 to 330 which were operated in response to the last code signals which were received will be unlocked. The code for the nineteen position will be impressed on relays 326 to 330. In response to this they will establish two circuits as has been explained from battery through the 19 advance lamp and from battery through the 18 retrogress lamp, through two individual chain circuits extending through the armatures of relays 326 to 330, to the armature of relay 350. When relay 307 operates at 18.98 degrees it connects ground to its M contact. As indicated in the first column of Fig. 4 during this interval relay 301 is in the released condition. The operation of relay 307 at 18.98 degrees, while relay 301 is released, establishes a circuit from ground through relay contact 307M, through relay contact 6S of relay 301 and the bottom winding of relay 350. Full current flows in this path. The armature of relay 350 will be operated to engage its S contact. This condition will obtain during the transition interval while the vernier is in positions 98 and 99. When the vernier moves into position 19.00 degrees, as indicated in the sixth code group of the left-hand column of Fig. 4 relay 307 remains operated and relay 301 operates. This establishes a circuit from ground through relay contact 307M, the 6M contact of relay 301 and the top winding of relay 350 to bat-

tery. The armature of relay 350 will be actuated to its M contact. This will close the circuit of the 19 advance lamp and it will light. As the vernier continues to increase there is no change in the condition of relays 307 or 301 until, as indicated in the right-hand vertical column in the eighth code group from the top for the 19.03 degree position of the vernier relay 307 releases. This disconnects direct ground from the top winding of relay 350. But the armature of relay 350 is locked to its M contact by its locking path. The release of relay 307 operated relay 310. This disconnects relays 326 to 330 from conductors 226 to 230. Relay 310 also locks those of relays 326 which are operated by the 19 code. Those relays of relays 326 to 330 which have remained unoperated by the 19 code maintain their released positions, of course, without locking. When the vernier reaches positions 19.035 degrees, switch 245 opens. When vernier position 19.05 degrees is reached relay 308 operates supplying an additional locking path for relay 310 and preventing the reoperation of relay 307 on vernier settings other than 98 to 02. The circuit for the 19 lamp is therefore locked and the 19 lamp remains lighted.

Let it be assumed that the azimuth continues to increase for a time while cams 221 to 224 and 231 to 234 control the hundredths of a degree lamps to correspond. Let it be assumed that the azimuth passes through 19.45 degrees to 19.50 degrees and to 19.60 degrees. As the azimuth passed through 19.45 degrees to 19.50 degrees the 20 code shown as the zero code in Fig. 6 would be set up on contacts 216 to 220 by cams 211 to 215.

Let it be assumed that starting at 19.60 degrees the vernier is turned backwards. The 20 code would not be transmitted because, as has been shown, the vernier would have to be rotated to 19.965 degrees before switch 245 is even closed. As the vernier is rotated so as to lower its reading when the vernier passes through 19.50 degrees to 19.45 degrees, the 20 code would be wiped out and the 19 code would be reestablished. When the vernier position 19.04 degrees is reached relay 308 again releases unlocking the right-hand locking path of relay 310. When vernier position 19.035 degrees is reached switch 245 recloses. Relay 301, as indicated in the left-hand column of Fig. 4, is operated at this time but it is ineffectual because relay 307 is released, as shown in the right-hand column of Fig. 4. At vernier position 19.01 degrees relay 307 reoperates. This unlocks the left-hand winding of relay 310 which releases its armature to S in turn unlocking relays 326 to 330. The code for 19 is impressed on relays 326 to 330. This will involve no change in the settings of the relays as the code is the same as last sent. With the armatures of both relays 301 and 307 operated to engage their M contacts a circuit is established through the top winding of relay 350. This continues to hold the armature of relay 350 on M momentarily. At position 99 of the vernier, corresponding to position 18.99 degrees, as shown in the fifth code group from the top in the left-hand column of Fig. 4, relay 301 releases. Relay 307 remains operated as indicated in the fifth code group from the top of the right-hand column of Fig. 4. This establishes a circuit through the bottom winding of relay 350. Full current flows through the bottom winding, preponderating over the holding current in the top winding of relay 350 and the armature of relay 350 is actuated to engage its S contact. This closes the circuit through the 18 lamp. Relay

301 remains released and at 18.97 degrees relay 307 releases. This disconnects direct ground from the bottom winding of relay 350 but the armature of relay 350 is maintained on its S contact by its holding circuit. The release of relay 307 at vernier position 97 reoperates relay 310. This again disconnects relays 326 to 330 from conductors 226 to 230 and reestablishes the locking path for those of the relays which have been operated by the degree code. At 96.5 switch 245 again reopens. At 95 relay 308 again releases. The circuit for the 18 lamp is locked lighted until the next cycle.

What is claimed is:

1. In a data transmission system, an observing station, a receiving station, means at said observing station for making measurements, means at said observing station for translating said measurements into a four-digit number, means at said observing station for translating each of the ten possible numerals in the units place in said number into a particular one of ten of sixteen possible code combinations of electrical impulses in accordance with a four-element permutation code, means at said observing station for impressing said combination of impulses simultaneously on four conductors comprising a first channel interconnecting said stations, means at said observing station for translating each of the ten possible numerals in the tens place in said number into a particular one of ten of thirty-two possible code combinations of electrical impulses in accordance with a five-element permutation code, means at said observing station for impressing said electrical impulses, defining the numeral in the tens positions, simultaneously, at a first time, on four of five other conducting elements comprising a second channel interconnecting said stations, means at said observing station for translating each of the numerals in the combined hundreds and thousands positions in said number into code combinations of electrical impulses other than assigned for said numerals in the tens positions in accordance with said five-element code and means at said observing station for impressing simultaneously at a second time signal impulses defining said combined numerals in said hundreds and said thousands positions in said number on said five conducting elements comprising said second channel.

2. In a data transmission system, a transmission channel, five separate independent conducting elements in said channel corresponding to five elements in a permutation code, means connected to said channel for translating any numeral in the units place in a three-digit number into signal impulses in accordance with combinations in said five-element code requiring for transmission changes in the conditions of four of said conducting elements only, while said fifth conducting element remains unchanged in one of its two possible conditions, and means for translating combined digits in the tens and hundreds places in said number into single code combinations requiring changes in the conditions of all of said five conducting elements.

3. In a data transmission system, an observing station, a receiving station, a plurality of separate independent transmitting channels connecting said stations, a plurality of separate independent conducting elements in each of said channels, means, responsive to the setting of a measuring instrument to make a measurement, for simultaneously impressing on said channels signal impulses in accordance with separate per-

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mutation codes to identify separate portions of a multidigit number instantaneously a plurality of decoding devices at said receiving station connected individually to said channels, locking means and unlocking means for a first of said devices, a plurality of indicators connected individually to said devices, means connected to said locking means for locking said first of said devices in response to the reception of a first particular code combination by a second of said devices, and means, connected to said unlocking means, for unlocking said first of said devices in response to the reception of a second particular code combination by said second of said devices.

4. In a data transmission system, an observing station, an indicating station, a plurality of separate independent transmission channels interconnecting said stations, a plurality of electrical contacts, connected to each of said channels arranged for the instantaneous transmission of multielement signal impulses in accordance with separate independent permutation codes defining separate portions of a multidigit number, a single control means common to all of said contacts for establishing signal combinations in accordance with said codes, a plurality of separate independent indicating devices at said indicating station for indicating said portions simultaneously, relay decoding circuits individual to each of said indicating devices, intermediate said indicating devices and said channels, two of said decoding circuits connected to one of said channels, and means for conditioning one of said two decoding circuits to respond only to particular permuta-

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tion code combinations received over said channel to which it is connected.

5. In a data transmission system, a receiving station, a first group of relays thereat selectively responsive to the reception at said receiving station of combinations of signal impulses in accordance with a first permutation code, a second group of relays at said station, independent of said first group of relays, selectively responsive to the reception at said receiving station of combinations of signal impulses in accordance with a second permutation code, independent of said first permutation code, a single measuring means at a transmitting station connected to said relays, a single common permutation code signal control means connected to said measuring means, for controlling the generation of combinations of impulses in accordance with both of said codes simultaneously to control said relays, means interconnecting said first and said second relay groups, responsive to the reception of a first particular signal code combination by said first group, for locking the relays of said second group, and means responsive to the reception of a second particular signal code combination by said first group for unlocking the relays of said second group.

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Administratrix of the Estate of Fullerton S. Kinkead, Deceased.